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Cover Photos :

Top Left: Weedy Plot 90 DAS; **Inset**: Broadleaf weeds (BLW) dominance in the second year; **Top Middle**: Symptoms of pinoxaden on *Avena ludoviciana* 10 DAT; **Top Right**: Traxos (clodinafop+pinoxaden) 60 g/ha on grassy weeds (no effect on BLW) 90 DAS; **Inset**: Traxos + Carfentrazone 60+20 g/ha 2 DAT on BLW; **Bottom Left**: Traxos + Metsulfuron 60+4 g/ha 3 WAT; **Bottom Middle**: Sulfosulfuron + Metsulfuron (Ready-mix) 32 g/ha, poor control of *A. ludoviciana* 6 WAT; **Bottom Right**: Traxos + Carfentrazone 60+20 g/ha on grassy and BLW 6 WAT. For more information read article on **Page 1-8**. Cover Design and all photos courtesy Dr. Samunder Singh, Department of Agronomy, CCSHAU Hisar 125 004, India.

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Evaluation of Traxos 5% EC (Pinoxaden + Clodinofop propargyl) against *Phalaris minor* and other grassy weeds in Wheat

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ABSTACT

Weed infestation is one of the major constraints in sustainable wheat production. Farmers of N-W India largely depend on herbicides for controlling weeds in wheat; however, continuous use of grassy herbicides resulted not only in weed flora shift towards broadleaf weeds but also evolution of resistance to graminicides. Traxos (ready mix of pinoxaden 2.53% + clodinafop propargyl 2.53% W/W) was evaluated at 40, 50, 60 and 120 g/ha alone and its 50 g dose tank mixed with metsulfuron 4 g or carfentrazone 20 g or 2,4-D ester 500 g/ha and compared with pinoxaden 50 g, clodinafop 60 g, fenoxaprop 120 g, ready-mix (RM) of sulfosulfuron + metsulfuron 32 g/ha along with an untreated weedy check with three replications in RBD design in research farm of CCS HAU Hisar against grassy and broadleaf weeds during 2011-12 and 2012-13. Traxos 60 g/ha provided effective control of *Avena ludoviciana* and *Phalaris minor* and was better than its 40 g/ha dose, but had no effect on broadleaf weeds. Tank mix of Traxos 50 g/ha with carfentrazone or metsulfuron or 2,4-D ester and sulfosulfuron + metsulfuron (RM) provided effective control of grassy and broadleaf weeds. Sulfosulfuron + metsulfuron (RM) was less effective against *A. ludoviciana* than *P. minor*, whereas lower efficacy of fenoxaprop was observed on *P. minor*. Traxos 60 g/ha provided lower dry weight of grassy weeds, higher tillers and wheat grain yield compared to its 40 g/ha dose, but was statistically similar to pinoxaden, clodinafop or fenoxaprop. Lower weed population, weeds dry weight and higher tillers and grain yield was recorded with tank mix application of Traxos 50 g + carfentrazone 20 g followed by tank mix of metsulfuron 4 g and 2,4-D ester 500 g/ha or sulfosulfuron + metsulfuron 32 g/ha (RM), during both the years; though there was no statistically significant differences among the herbicide mixtures. Herbicides applied in wheat had neither crop phytotoxicity nor any residual effect on succeeding mung bean crop observed on its germination and crop growth observed 30 days after planting in wheat treated plots under zero-till sowing of mung bean.

Key words : Herbicide mixture, wild oat, littleseed canarygrass, broadleaf weeds, weed control efficacy, residual effect, mung bean

INTODUCTION

Wheat (*Tritcum aestivum* L) is the most staple food for huge global population as it is grown in 225 m ha worldwide with a production of 735 mt during 2015-16 and productivity of 3.27 t/ha. In India, it is second to rice in terms of area and production, producing 90-95 mt of wheat from 29-31 m ha area. Rice-wheat is the most common crop sequence in the Indo-Gangetic plains with 13.5 m ha area. In Haryana wheat was produced in 2.5 m ha area producing 11.6 mt with a productivity of 40.66 q/ha during 2014-15. We have almost reached a plateau in wheat productivity per unit area due to various biotic and abiotic factors. Still wheat is considered most assured crop in the country and essential for country's nutritional security. Losses caused by wheat are more than any other pests as weeds are called silent robbers. These losses depend on the infesting weed type, its intensity, and agronomic practices adopted in wheat cultivation (Singh *et al*., 1999; Singh 2007). Grassy weeds *viz*. wild oat and littleseed canarygrass have been the most prevalent weeds of wheat (Singh *et al*., 1995a). Wild oat has been most competitive among the two, significantly reducing crop growth and productivity (Singh *et al*., 1995b; Balyan *et al*., 1991). Losses caused by weeds in wheat vary from 30-50%, but in extreme case there could be complete crop failure (Malik and Singh, 1995, Singh *et al*., 1999). Herbicide resistance is the major cause of yield loss as continuous use of herbicides of same site of action resulted in multiple herbicide resistance (Singh *et al*., 2009; Singh 2014). The situation is further complicated due to shift in weed flora towards difficult to control weeds as a result of using the same agronomic practices (herbicides). Wheat is infested with both grassy and broadleaf weeds and effective weed management require an integrated approach using both chemical and non-chemical approaches (Chhokar and Malik 2002; Chhokar *et al*., 2012; Singh 2007; Singh and Chhokar, 2011). For effective management of complex weed flora, mixture of more than one herbicide is required. Herbicide mixtures not only increase weed control efficacy against complex weed flora (Singh *et al*., 2008, 2011), they are also useful in delaying herbicide resistance (Wrubel and Gressel, 1994). The mixture should have a wide spectrum of weed control without crop injury and no residual effect on succeeding sensitive crops after wheat. The present experiment was conducted to evaluate a mixture of pinoxaden and clodinafop (Traxos 5% EC) used alone and tank mixed with broadleaf herbicides in wheat and residual effect on succeeding sensitive crop.

MATERIALS AND METHODS

Wheat CV. PBW 502 and WH 711 was planted on 21 and 30 November during 2011 and 2012, respectively at the Research Farm of Agronomy Department, CCS Haryana Agricultural University, Hisar, using a seed rate of 100 kg/ha. A recommended dose of fertilizer (150 kg N, 60 kg P_2O_5 and 10 kg $ZnSo_4$/ha) was applied at sowing (except nitrogen which was applied in two splits). Planting was done by using ZT drill (18 cm R-R spacing) after preparing the field thoroughly (using disc harrow, cultivator and planker). Ready-mix (RM) of Traxos 5% EC (pinoxaden 2.53% + clodinofop propargyl 2.53% W/W) at 40, 50, 60 and 120 g/ha was compared with pinoxaden 50 g, clodinafop-propargyl 60 g, fenoxaprop-P-ethyl 120 g, sulfosulfuron + metsulfuron 32 g (RM), tank mix of Traxos 50 g + metsulfuron/carfentrazone or 2,4-D ester at 4/20 or 500 g/ha and an untreated control in a plot size of 3.2 m x 10 m (3.2 m x 8 m in the second year), replicated thrice in an RBD design. The crop was raised as per university Package of Practices. Herbicides were sprayed 40-45 days after sowing (DAS) using backpack sprayer delivering 300 l/ha volume. Observations were recorded for crop injury and percent control of weeds on a 0-100 scale (0=no effect and 100=complete mortality) at 75 and 120 DAS. The field was infested with natural population of *Phalaris minor* and *Avena ludoviciana* among the grasses and *Rumex dentatus, Medicago denticulata, Melilotus indica, Coronopus didymus, Anagallis arvensis, Convolvulus arvensis, Lathyrus aphaca, Spergula arvensis, Chenopodium album* and *Euphorbia heliscopia* among broadleaf in the order of dominance. Population of broadleaf weeds was greater during the second year of study. Weed population was recorded at 30 and 120 DAS and weed dry weight at 120 DAS. Yield parameters and crop yield was recorded at harvest. Crop was harvested on 30 April 2012 and 25 April 2013. Due to variations in weed population during both the years and data were analyzed separately using SPSS program. Least significance difference (LSD) test was applied at 5% probability level to test the significance of mean treatment values and One Way ANOVA using Tukey[b] test was applied to separate treatments effects.

After wheat harvest, mung-bean CV MH 125 during 2012 and MH 318 during 2013 was planted in plots treated with wheat herbicides without disturbing the original layout. Zero-till sowing of mung bean was done on 17 June 2012 and 7 May 2013. Residual effect of wheat herbicides was recorded as per CIB guidelines (chlorosis, necrosis, yellowing, epinasty & hyponasty) 10 DAS and plant height was recorded 30 DAS of crop.

RESULTS AND DISCUSSION

Effect on weeds

During the first year (2011-12), wild oat (*Avena ludoviciana*), littleseed canarygrass (*Phalaris minor*) and broadleaf weed population varied from 15-19, 20-24 and 85-111 plants/m^2, respectively that was uniformly distributed in all the treatment plots at 30 DAS (Table 1). At 120 DAS, there was complete control of wild oat by Traxos at all its doses except at 40 g/ha. Pinoxaden 50 g/ha, clodinafop 60 g/ha, fenoxaprop 120 g/ha and Traxos 50 g/ha tank mixed with metsulfuron 4 g/ha or carfentrazone 20 g/ha provided excellent control of wild oat. The efficacy of ready-mix sulfosulfuron + metsulfuron; however, was lower on wild oat, which was similar to 40 g/ha Traxos. Tank mix of Traxos + 2,4-D ester 50+500 g/ha had only one plant of wild oat

Table 1. Effect of different weed control treatments on Avena ludoviciana, Phalaris minor and broadleaf weeds population, dry weight and mortality during 2011-12

Treatments (g/ha)	Weed population (No/m^2) 30 DAS			Weed population (No/m^2) 120 DAS			Weeds dry weight (g/m^2) 120 DAS			Mortality % 75 DAS			Mortality % 120 DAS		
	Avena	*Phalaris*	BLW	*Avena*	*Phalaris*	BLW	*Avena*	*Phalaris*	BLW	*Avena*	*Phalaris*	BLW	*Avena*	*Phalaris*	BLW
Traxos 40	16	21	96	5	5	73	50	47	340	92	87	0	90	80	0
Traxos 50	15	23	111	0	1	81	0	12	393	100	97	0	98	98	0
Traxos 60	17	24	92	0	0	75	0	0	389	100	100	0	100	98	0
Traxos 120	17	20	85	0	0	75	0	0	386	100	100	0	100	100	0
Pinoxaden 50	19	21	91	0	0	74	0	0	393	100	100	0	100	98	0
Clodinafop 60	19	23	89	0	1	73	0	12	399	100	97	0	95	92	0
Fenoxaprop 120	17	23	91	0	3	75	0	27	327	100	93	0	98	92	0
SSN+MSM (RM) 32	16	21	99	4	0	16	47	0	27	93	97	87	90	100	92
Traxos+MSM 50+4	17	23	99	0	1	21	0	2	31	98	98	90	100	97	92
Traxos+CZN 50+20	16	24	97	0	1	8	0	1	15	98	98	92	100	97	93
Traxos+2,4-D 50+500	17	23	96	0	1	16	0	3	25	98	98	90	100	98	90
Untreated control	17	23	85	21	20	50	494	259	413	0	0	0	0	0	0
SEm	2	3	11	2	2	7	16	20	47	2	3	2	2	3.47	1
LSD (P005)	NS	NS	NS	3	4	14	33	42	98	5	6	3	3	7	2

Traxos = (pinoxaden + clodinafop), MSM = metsulfuron, CZN = carfentrazone, NS = non-significant.

compared to 23 plants/m^2 in control treatment. Traxos 40 g/ha, fenoxaprop 120 g/ha and tank mix of Traxos+2,4-D ester 50+500 g/ha recorded 4, 5 and 3 plants/m^2 of littleseed canarygrass, respectively at 120 DAS compared to 29 plants/m^2 in the control treatment. No plants of littleseed canarygrass were observed in Traxos 60 and 120 g/ha, pinoxaden 50 g/ha and tank mix of Traxos + metsulfuron 50+4 g/ha, where as other treatments registered only one plant/m^2. Traxos, pinoxaden, clodinafop and fenoxaprop recorded 73-81 plants/m^2 of broadleaf weeds that was similar to control treatment (Table 1). Tank mix of metsulfuron or carfentrazone or 2,4-D ester with Traxos 50 g/ha and RM of sulfosulfuron + metsulfuron 32 g/ha resulted in 58, 84, 68 and 68% lower population of broadleaf weeds compared to control treatment; though all the mixtures were statistically similar among themselves.

During the second year (2012-13), wild oat, littleseed canarygrass and broadleaf weed population 30 DAS ranged from 17-23, 25-29, and 249-340 plants/m^2, respectively (Table 2). Weed population before spray (30 DAS) was non-significant among the treatments. Traxos 50, 60 and 120 g/ha, pinoxaden 50 g, clodinafop 60 g, fenoxaprop 120 g/ha and Traxos 50 g tank mixed with metsulfuron 4 g or carfentrazone 20 g registered no population of wild oat at 120 DAS. However, lower rate of Traxos (40 g/h), RM of sulfosulfuron + metsulfuron (32 g/ha), and tank mix of Traxos + 2,4-D ester 50+500 g/ha recorded 5, 4 and 1 plant/m^2 of wild oat, respectively compared to 23 plants/m^2 in control plot (Table 2). Littleseed canarygrass population at 120 DAS was significantly higher in weedy check and fenoxaprop 120 g/ha compared to Traxos 60, 120 g/ha, pinoxaden 50 g/ha and Traxos 50 g + metsulfuron 4 g or carfentrazone 20 g/ha. Traxos, pinoxaden, clodinafop and fenoxaprop being only grass herbicides had no effect on broadleaf weeds as they recorded 151-163 plants of broadleaf weeds which were similar to control treatment (Table 1). Tank mix of metsulfuron or carfentrazone or 2,4-D ester with Traxos 50 g/ha and RM of sulfosulfuron + metsulfuron 32 g/ha resulted in >89% lower population of broadleaf weeds compared to control treatment; though all the mixtures were statistically similar among themselves.

Weed Dry weight

Weed dry weight of wild oat and littleseed canarygrass was significantly reduced by all herbicidal treatments at 120 DAS compared to weedy check during both the years (Table 1 & 2).

Maximum dry weight of wild oat among herbicidal treatments was recorded with Traxos 40 g/ha and RM of sulfosulfuron + metsulfuron 32 g/ha which was 90 and 85% lower compared to weedy check treatments during 2011-12 and 2012-13, respectively. Similarly, weed dry weight reduction of littleseed canarygrass with Traxos 40 g/ha was 82% and 88% compared to control, respectively during both the years (Table 1 & 2); reduction with 50 g/ha of Traxos was >95%, whereas no dry weight was recorded with its higher doses. Pinoxaden (100%) was more effective than clodinafop (95%) and fenoxaprop (90 & 81%) in reducing the dry weight of littleseed canarygrass during both the years; though the differences were not statistically significant. All other herbicidal treatments provided 99-100% reduction in dry weight of littleseed canarygrass except tank mix of Traxos + 2,4-D ester at 50+500 g/ha (93%) during the second year (Table 1 & 2). Dry matter accumulation by broadleaf weeds was more during 2012-13 compared to 2011-12 at 120 DAS (Table 1 & 2). Grass weed herbicides had no effect on broadleaf weeds dry weight, but mixture with broadleaf herbicides reduced the dry weight of broadleaf weeds from 89-96% (Table 1 & 2). No particular trend was observed among the herbicide mixtures in reducing the dry weight of broadleaf weeds during both the years as there were no statistically significant differences among themselves.

Weed Mortality

All the grassy herbicides provided >87% control of wild oat and littleseed canarygrass during 2001-12 and 2012-13 at 75 DAS (Table 1 & 2). Traxos 40 g/ha was significantly poor on grassy weeds compared to its higher doses during both the years. Efficacy of sulfosulfuron + metsulfuron 32 g/ha (RM) on wild oat was similar to Traxos 40 g/ha, but significantly lower than higher rates of Traxos or its tank mix with metsulfuron or carfentrazone or 2,4-D ester and pinoxaden, clodinafop or fenoxaprop during both the years. Lower efficacy of fenoxaprop was recorded against littleseed canarygrass during both the year which was similar to lower rates of Traxos (Table 1 & 2). All other herbicide treatments provided >95% control of littleseed canarygrass. As grassy herbicides had no efficacy on broadleaf weeds, tank mix of Traxos with

Table 2. Effect of different weed control treatments on Avena ludoviciana, Phalaris minor and broadleaf weeds population, dry weight and mortality during 2012-13

Treatments (g/ha)	Weed population (No/m^2) 30 DAS			Weed population (No/m^2) 120 DAS			Weeds dry weight (g/m^2) 120 DAS			Mortality % 75 DAS			Mortality % 120 DAS		
	Avena	*Phalaris*	BLW	*Avena*	*Phalaris*	BLW	*Avena*	*Phalaris*	BLW	*Avena*	*Phalaris*	BLW	*Avena*	*Phalaris*	BLW
Traxos 40	19	28	249	5	4	163	58	26	1037	95	90	0	92	92	0
Traxos 50	17	25	255	0	1	151	0	9	1152	100	97	0	100	95	0
Traxos 60	23	28	295	0	0	169	0	0	995	100	100	0	100	97	0
Traxos 120	20	27	307	0	0	143	0	0	1130	100	100	0	100	100	0
Pinoxaden 50	21	29	299	0	0	155	0	0	1148	100	100	0	100	100	0
Clodinafop 60	23	27	340	0	1	162	0	12	1136	100	97	0	98	95	0
Fenoxaprop 120	23	28	292	0	5	159	0	42	1070	100	87	0	97	92	0
SSN+MSM (RM) 32	23	27	283	4	1	16	57	4	155	87	96	93	88	97	92
Traxos+MSM 50+4	21	29	309	0	0	16	0	0	180	98	100	97	98	100	93
Traxos+CZN 50+20	21	29	300	0	0	16	0	0	170	98	98	97	98	98	92
Traxos+2,4-D 50+500	23	25	293	1	3	17	12	15	184	95	98	93	97	98	93
Untreated control	20	29	339	23	29	150	388	223	1749	0	0	0	0	0	0
SEm	3.44	5.33	38	1	2	20	24	19	54	2	3	3	2	3	1
LSD (P005)	NS	NS	NS	3	4	42	50	38	112	5	6	6	4	5	3

Traxos = (pinoxaden + clodinafop), MSM = metsulfuron, CZN = carfentrazone, NS = non-significant.

metsulfuron, carfentrazone or 2,4-D ester provided >90% control of infesting broadleaf weeds during both the years. Efficacy of RM of sulfosulfuron (87%) at 75 DAS was lower on broadleaf weeds during 2011-12, but it was statistically similar to other herbicide mixtures during 2012-13 and at 120 DAS during both the years (Table 1 & 2). At 120 DAS, weed control efficacy against infesting weeds was reduced compared to 75 DAS, but similar trend was recorded for wild oat and littleseed canarygrass (Table 1 & 2).

Yield parameters and wheat yield

There was no crop phytotoxicity as plant height of wheat recorded at 120 DAS exhibited no reduction with any of the herbicidal treatments compared to control check during both the years, though plant height was more during the second year (Table 3). On the other hand tiller number/running meter row length was more during 2011-12 compared to 2012-13, but increased significantly with increase in Traxos doses from 40 g/ha to 60 g/ha rate during both the years (Table 3). Maximum tillers among the grassy herbicides were recorded with pinoxaden 50 g/ha, during the first and Traxos 60 g/ha during the second year which were statistically similar to all grassy herbicides except Traxos 40 g/ha (Table 3). Tank or RM herbicides application resulted in 60% higher tillers compared to weedy check plot during both the years and were also significantly higher than grass only herbicides.

Weeds reduced 51% grain yield of wheat in weedy check plot compared to tank mix of Traxos 50 g + carfentrazone 20 g/ha during 2011-12 (Table 3). Highest grain yield of wheat was recorded with Traxos 50 g/ha + carfentrazone 20 g or metsulfuron 4 g/ha which was significantly higher than Traxos 40 and 50 g/ha, clodinafop 60 g and fenoxaprop 120 g/ha, but statistically similar to tank mix of Traxos + 2,4-D ester or RM of sulfosulfuron + metsulfuron 32 g/ha during 2011-12. Traxos 60 g/ha produced similar grain yield to that of its double dose or pinoxaden 50 g/ha, but higher than its lower rate during 2011-12 (Table 3). During 2012-13, Traxos 120 g/ha yielded 45.57 g/ha wheat grain yield that was statistically similar to all other grass herbicides except its 40 g/ha rate. Tank mix or RM herbicides produced significantly higher wheat grain yield compared to Traxos, pinoxaden, clodinafop or fenoxaprop, but there were no statistical differences in grain yield among the herbicide mixtures (Table 3).

There was no phytotoxicity (chlorisis, necrosis, yellowing, epinasty or hyponasty) due to the application of Traxos even at 2X dose of 120 g/ha (Table 3). Similarly, no crop phytotoxicity was observed due to alone application of pinoxaden and clodinafop or fenoxaprop. Plant height of wheat (120 DAS) was not affected by any herbicides (Table 3). Wheat tillers were significantly affected by weeds infestation as 29% lower numbers of tillers were recorded in weedy plots compared to Traxos 60 g/ha. Traxos 40 g/ha resulted in lower numbers of tillers compared to its higher dose or alone application of pinoxaden or clodinafop or fenoxaprop. Highest wheat grain yield of 55.49 q/ha was recorded with Traxos 60 g/ha which was 9 and 29% higher than its lower dose of 40 g/ha and untreated control, respectively (Table 1). Weedy check plots produced 34.51 q/ha wheat grain yield which was 50% lower than tank mix of Traxos + carfentrazone or metsulfuron during 2012-13.

Effect of wheat herbicides on succeeding mung bean

Mung bean planted after harvesting wheat crop for bioassay study for residual effect of herbicides applied in wheat without disturbing wheat plots exhibited no chlorosis, necrosis, yellowing, epinasty and hyponasty after 10 days of sowing on mung bean (data not included). Similarly, no reduction in plant height was observed at 30 DAS during both the years of the study (Table 3).

Traxos 60 g/ha was effective against both wild oat and littleseed canarygrass and was comparable to pinoxaden 50 g/ha and had an edge over clodinafop and fenoxaprop in controlling littleseed canarygrass (Table 1 & 2), its tank mix with carfentrazone or metsulfuron or 2,4-D ester (50 g+20/4/500 g/ha) proved more effective in controlling not only grassy but broadleaf weeds and provided higher grain yield of wheat (Tables 1-3). Increased efficacy of tank mix of herbicides has also been reported (Singh *et al*., 2008; 2011) where mixture of broadleaf herbicides proved more effective against the target weed species compared to their individual applications. Traxos with broadleaf herbicides (carfentrazone/metsulfuron or 2,4-D ester) were better in controlling broadleaf weeds compared to ready-mix of sulfosulfuron + metsulfuron (Table 1 & 2); moreover, lower efficacy of ready-mix of sulfosulfuron + metsulfuron 32 g/ha was observed against wild oat. Pinoxaden has been found effective against both wild

Table 3. Effect of different weed control treatments on plant height of wheat, tillers, grain yield and residual effect on succeeding mung bean crop during 2011-12 and 2012-13

Treatments (g/ha)	Plant height (cm) 120 DAS		Tillers (No/mrl) 120 DAS		Wheat yield (q/ha)		Mung bean plant height (cm) 30 DAS	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2012	2013
Traxos 40	104	84	100	84	50.33	40.36	21	19
Traxos 50	102	85	118	87	52.94	42.45	21	19
Traxos 60	104	88	122	95	55.49	44.60	22	21
Traxos 120	104	88	124	94	55.29	45.57	20	20
Pinoxaden 50	109	86	126	94	54.87	45.18	21	18
Clodinafop 60	104	83	121	88	53.20	44.14	23	18
Fenoxaprop 120	102	82	120	84	53.10	43.49	20	20
SSN+MSM (RM) 32	104	82	136	106	58.25	51.04	20	18
Traxos+MSM 50+4	109	82	138	106	59.11	51.13	22	20
Traxos+CZN 50+20	104	82	139	105	59.52	51.83	23	21
Traxos+2,4-D 50+500	102	83	135	103	57.27	50.19	23	20
Untreated control	106	83	85	66	39.46	34.51	20	20
SEm	6	2	4	4	1.56	2.15	2	2
LSD (P005)	NS	NS	8	8	3.23	4.47	NS	NS

Traxos=(pinoxaden+clodinafop), MSM = metsulfuron, CZN = carfentrazone, NS = non-significant.

oat and littleseed canarygrass in wheat and barley (Chhokar *et al*., 2007; Singh and Punia, 2007). Pinoxaden tank-mixed with carfentrazone, metsulfuron and 2,4-D ester has been recommended for the control of broad-spectrum of weed control in wheat and barley and there was no incompatibility of the mixture; rather pinoxaden tank mixed with carfentrazone increased efficacy against littleseed canarygrass (Singh *et al*., 2010). Herbicide mixture or their sequential application has been found more effective in managing the resistant littleseed canarygrass (Singh, 2015). Tank mix of Traxos with carfentrazone/metsulfuron or 2,4-D ester had neither adverse effect on wheat growth, nor there was any residual effect on succeeding sensitive crop of mung bean.

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Economics of bed planted wheat as influenced by varying moisture regimes

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ABSTRACT

An experiment was conducted at Research Farm of Chaudhary Charan Singh Haryana Agricultural University, Hisar on sandy loam soil during *rabi* seasons of 2003-04 and 2004-05 to study the effect of planting method on economics of bed planted wheat. The experiment was laid out in strip plot design and treatments comprised of two methods of planting *viz.* bed and conventional planting on main plot and three moisture regimes *viz*. irrigation at CRI+100 mm, CRI+150 mm and CRI + 200 mm CPE in sub plots, replicated thrice. It was found that grain yield of wheat was not affected due to planting method. However, higher gross and net returns were obtained by planting of wheat on beds. Overall, bed planting was profitable with reduced cost of cultivation. Among the moisture regimes, 6.17 and 11.86% higher grain yield in 2003-04 and 9.26 and 6.98% higher grain yield in 2004-05 was recorded with CRI+100 mm CPE than CRI+150 mm CPE and CRI+200 mm CPE. The lowest net returns (11459 Rs. ha^{-1}) in the year 2003-04 were obtained with lower moisture regime *i.e.* irrigations at CRI+200 mm CPE while in the year 2004-05, it was with medium moisture regime *i.e.* irrigation at CRI+150 mm CPE.

Key words : Bed planting, moisture regime, wheat, economics

INTRODUCTION

Irrigation water management is one of the major factors responsible for getting higher yield. As more than 90% of the water is used for irrigation. Surface irrigation is an ancient and widely used technique for irrigation in the Indo-Gangetic Plains of South Asia. Surface irrigation contributes to low application efficiency, which depends upon many factors, including infiltration soil characteristics, field undulation, intake discharge and run-off. Development of suitable crop-specific layouts can improve the application efficiency of available irrigation water resources. Crop planted on beds receives water through seepage, it is not in contact with flooded water and consequently lodges less than surface planted crops. Bed planting also improves seedling establishment. It is more economical, viable and ecofriendly compared to conventional flat sowing. Wheat production on raised beds increases production with increased production efficiency and overall profitability (Yadav *et al*., 2002). There was 46-56% saving in fuel (diesel) with equal saving in time and quality of water given through irrigations at various stages in wheat. So, to achieve higher net returns, one alternative is to plant wheat on top of the raised beds and apply irrigation in furrows between the beds. Moreover, wheat sown on bed results in higher net return with reduced cost of cultivation and increased monetary benefit over the flat sowing. But the required information on the optimum soil moisture regimes of bed planted wheat for a semi-arid climate is not available. Keeping this in view present investigation was conducted to study the effect of bed planting in the semi-arid region.

MATERIALS AND METHODS

The experiment was conducted during the *Rabi* seasons of 2003-04 and 2004-05 at Soil Research Farm of CCSHAU, Hisar. The experimental site is situated at 29° 10' North latitude and 75° 46' East longitude at an elevation of 215.2 m above mean sea level. The experiment field was sandy loam (63.5% sand, 17.3% silt and 19.2% clay) in texture. Soil was low in N, medium in P and high in K status. The soil organic carbon content was 0.26% and pH was slightly alkaline (7.50). The whole experiment was conducted in strip plot design with three replication. The treatments comprised of two methods of planting *viz*., bed and conventional in main plot and three moisture regimes *viz*., irrigation at CRI+100 mm, CRI+150 mm and CRI+200 mm CPE in sub plots. The basic infiltration rate at the site was 5.3 mm/h. The gravimetric moisture content at -0.03 and -1.5 MPa soil water potential was 20.9 and 6.5% respectively.

Wheat cv. WH-711 was planted on 24th November 2003 and 5th November 2004 at a row spacing of 22.5 cm under conventional planting and on beds with a bed planter. The width of the bed was 40 cm and two rows of wheat at 20 cm were planted on each side of the bed. The furrows were about 20 cm deep having a 'V' notch type shape. Thus, the effective distance between the two rows of the furrows was 65 cm. Pre-sown irrigation of 5.9 and 6.4 cm depth was applied on 13th November 2003 and 26th October 2004 during the two *rabi* seasons. A common irrigation at CRI stage was applied in all the treatments on December 25, 2003 and November 29, 2004. Thereafter, irrigations were scheduled as per treatments. Daily pan evaporation and rainfall data from sowing till maturity was collected from the Meteorological observatory located at the Research Farm of Chaudhary Charan Singh Haryana Agricultural University, Hisar. These were then computed to have their cumulative values. These values were used to know the dates of irrigation water to be applied in each treatment. The detail of irrigation (dates and amount) under different moisture regimes in bed and conventional planted wheat are presented in Table 1.

In treatment CRI+100 mm CPE four post-sown irrigations were applied in 2003-04 as given in Table 1, with 22.9 and 27.2 cm water in bed and conventional planted plots, respectively. In moisture regimes of irrigation at CRI+150 mm CPE, three post-sown irrigations were applied. Whereas, in CRI+200 mm CPE moisture regimes, only two irrigations were applied. The yield was measured at the time of harvest. The cost of field preparation, sowing of seeds, thinning, weeding, plant protection, harvesting and cleaning contributed to fixed cost. The variable cost included the cost of irrigation charges and labour for application of fertilizer and irrigation. The gross income of crop was worked out from average seed yield produced under different planting and irrigation treatments. To find out the net income, the cost of each treatment was subtracted from the total gross income.

RESULTS AND DISCUSSION

The cost of inputs and the produce and the net benefit under different treatments has been given in Table 2. The data revealed that the input cost was reduced by 17 and 16.3% in bed planting as compared to conventional flat sowing in 2003-04 and 2004-05, respectively.

The net profit with conventional flat sowing was Rs. 11146 and 16577 ha^{-1} in the year 2003-04 and 2004-05 which increased to Rs. 13769 and 12993 ha^{-1} with

Table 1. Details of moisture regimes [dates and depth (cm) of irrigation] under different treatments in wheat

Irrigation No.	Moisture regimes, CPE						
	Dates	CRI+100 mm		CRI+150 mm		CRI+200 mm	
		Bed	Conventional	Bed	Conventional	Bed	Conventional
Pre-sown	13.11.03	5.6	6.8	5.5	6.7	5.5	6.8
2003-04							
At CRI	25.12.03	5.4	6.3	5.3	6.3	5.4	6.2
1st	01.3.04	5.8	6.9	-	-	-	-
2nd	15.3.04	-	-	6.2	7.2	-	-
3rd	25.3.04	5.8	6.8	-	-	6.5	7.5
4th	06.4.04	5.9	7.2	6.3	7.4	-	-
Total post-sown	22.9	27.2	17.8	20.9	11.9	13.7	
Grand total	28.5	34.0	23.3	27.6	17.4	20.5	
2004-05							
Pre -sown	26.10.04	6.4	6.4	6.4	6.4	6.4	6.4
At CRI	29.11.04	5.4	6.5	5.5	6.5	5.5	6.5
1st	12.1.05	5.8	6.2	-	-	-	-
Total post-sown	11.2	12.7	5.5	6.5	5.5	6.5	
Grand total	17.6	19.1	11.9	12.9	11.9	12.9	

Table 2. Effect of planting methods and moisture regimes on economics of wheat

Planting method	Grain yield (kg/ha)		Cost of cultivation (Rs./ha)		Gross Return (Rs./ha)		Net Return (Rs./ha)	
	2003-04	2004-05	2003-04	2004-05	2003-04	2004-05	2003-04	2004-05
Bed	4348	4633	23700	23066	37469	39643	13769	13769
Conventional	4537	4670	28520	27563	39666	34055	11146	11146
S. Em±	67	82	-	-	-	-	-	-
CD at 5%	NS	NS	-	-	-	-	-	-
Moisture regimes (irrigation at)								
CRI+100 mm CPE	4727	4913	27126	25989	40619	41751	13493	15762
CRI+150 mm CPE	4435	4458	26159	24978	38583	38923	12424	13945
CRI+200 mm CPE	4166	4583	25046	24978	36505	39621	11459	14643
S. Em±	110.8	120	-	-	-	-	-	-
CD at 5%	353	404	-	-	-	-	-	-

planting of wheat on beds. Thus there was an additional benefit of Rs. 2623 and Rs. 3584 ha^{-1} with bed planting over conventional flat sowing. This might be due to lower seed rate, cost of irrigation water and fuel (diesel) used in bed planting. Increase in net returns by 20 to 30 % and fall in production cost with bed planting system as compared to conventional method of sowing in wheat has also been reported by Sayre (2000) and Dhindwal *et al.* (2006). He further stated that average net profit for farmers (47) growing wheat on beds was higher than the farmers (17) growing wheat conventionally. Similar was the findings of Kumar (2001) and Mollah *et al.* (2009).

The lowest net returns (11459 Rs. ha^{-1}) in the year 2003-04 were obtained with lower moisture regime i.e. irrigations at CRI+200 mm CPE while in the year 2004-05, it was with medium moisture regime i.e. irrigation at CRI+150 mm CPE. Higher net returns with increasing irrigation ratio in wheat were also reported by Virdi (2003).

CONCLUSIONS

The present investigation it may be concluded that bed planting of wheat is the best option for higher productivity. The cost of cultivation was lower and net return was higher in bed planting than conventional method. Among the moisture regimes, highest net returns were achieved under CRI+200 mm CPE moisture regimes.

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Effect of preceding intercropping systems and nitrogen levels on wheat

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ABSTRACT

The investigation was carried out at the research farm of Chaudhary Charan Singh Haryana Agricultural University, Hisar during *Kharif* and *Rabi* seasons 2011-12 and 2012-13. The experimental design was split plot. There were three levels of nitrogen *viz.* 75 percent, 100 and 125% of recommended dose in sub plots and twelve different intercropping systems of *kharif* season in main plots. The wheat variety WH 1021 was tested for the study. The effect of different intercropping treatments as succeeding wheat nitrogen requirement was found significant. Wheat produced significantly higher grain yield when planted after pigeon pea (75 cm)+greengram (1:1 or 1:2) treatment as compared to pearlmillet intercroping tretments at the same row spacing and row ratio. Application of 100 percent RDN being at par with 125% RDN produced significantly higher grain yield of wheat as compared to 75% RDN. No interaction between N levels and intercropping systems (*kharif*) was found significant.

Key word : Pigeon pea, pearlmillet, greengram, plant height, yield attributes and yield, intercropping systems

INTRODUCTION

Pigeon pea (*Cajanus cajan* L.)-wheat (*Triticum aestivum* L.) is an efficient, potential and sustainable cropping system in northern plains. The introduction of short-duration varieties of pigeon pea and late sown wheat varieties have made pigeon pea-wheat sequence more feasible and acceptable to farmers in the wheat belt of North India, especially in areas with assured irrigation (Ahlawat *et al*. 1985). Wheat generally follows rainy season crops *viz.*, paddy, maize, sorghum and pearlmillet, which are highly nutrients exhaustive. Paddy - wheat is the most important cropping system which met the requirement of the nation. However, the continuous cultivation of cereals in a year on the same piece of land leads to imbalance in the soil fertility, resulting in decline in yield of both the crops. Exhaustive crops/cropping systems deteriorates the soil health by excessive mining of native fertility leaving hardly any crop residue which is necessary to maintain desired level of organic matter. Therefore, the nature and selection of the preceding crops deserve greater importance, while formulating fertilizer recommendation in crop production **(**Usadadiyai and Patel, 2013).

It has been reported that preceding crop of pigeon pea reduced the nitrogen requirement of wheat by 30 kg N/ha (Narwal *et al.*, 1983). With release of short duration pigeon pea varieties, the cropping sequence of pigeon pea-wheat has become popular in Haryana and Punjab (Faroda and Singh, 1983), owing to assured high returns. Nitrogen is required in large amount by high yielding crops and is often the most limiting plant nutrient in soil for optimum crop growth and yields. With the increasing cropping intensity fertilizer are needed to maintain the stable yield but these are costly. Therefore, there is need to be used them judiciously and efficiently. Due to biological nitrogen fixation by pigeon pea, the nitrogen requirement of wheat was reduced by more than 20 kg/ha, which was further increased with recycling of natural or induced (through 10% urea spray) litter fall (Ahlawat *et al.,* 2005). Inclusion of legumes in cropping system improves soil fertility (Lupwayi and Kennedy, 2007), thereby increasing the yield of succeeding crop (Mubarak and Singh, 2011). A lot of work has been done on nutrient management in pigeon pea and wheat crop alone. However, very less information is available on the effect of pearlmillet, greengram intercropping in pigeon pea and its residual effect on wheat. Therefore, in view of the above, the present investigation was planted.

MATERIALS AND METHODS

The experiment was conducted at the Agronomy Research Farm, CCS Haryana Agricultural University, Hisar during 2011 and 2012. It is situated at 29°10' N latitude, 75°46' E longitude and at an altitude of 215.2

meters above mean sea level. The experiment was laid to see the effect of the preceeding intercrops on wheat variety WH 1021 on the growth, yield attributes and yield. The *kharif* crops pigeon was as sole and in combination with pearlmillet and greengram at different spacing and rows in the kharif season during 2011 and 2012 resulting in 12 treatments. *Kharif* seasons treatments were superimposed with three nitrogen levels *i.e.* 75%, 100% and 125% of recommended dose of nitrogen of wheat as sub plots and replicated thrice. The soil of the experimental unit was sandy loam and the soil pH was 7.8 and 7.9, while the EC was 0.39 and 0.40 dSm^{-1} during 2011 and 2012, respectively. The organic carbon of the soil was 0.41 and 0.40% during both the years of study. The available N was estimated as 162.8 and 164.5 kg/ha during 2011 and 2012, respectively. The available phosphorus in the soil regime was 25.6 and 24.45 kg/ha with 305.5 and 304.65 kg/ha of available potassium.

RESULTS AND DISCUSSION

Growth and yield attributes of wheat

The different doses of nitrogen application influenced the plant height significantly at harvest stages of growth during both the years. The application of 100% RD of N significantly increased the plant height of wheat. Different intercropping systems of *kharif* season influenced plant height of wheat. Significantly taller plants were recorded when wheat was sown either after sole greengram at 30 cm or in combination with pigeon pea at 75 cm (Table 1). The increase was owing to higher amount of N which increased the nutritional environment and henceforth increased the meristematic activity of the plant. Kachroo and Razdan (2006) also reported positive effect of N application on growth of wheat.The application of increased dose of nitrogen brought about increase in yield attributes of wheat. Maximum tillers/mrl, number of grains per spike and thousand grain weight were recorded when 125% RD of N was applied during 2011 and 2012.

The maximum tillers/mrl of wheat were recorded when wheat succeeded after sole greengram. However, grains per spike and 1000 grain weight were not affected by intercropping system. The increasing vigour and growth in terms of plant height and effective tiller/meter row length owing to residual fertility lead to better development of yield attributes Ghanshyam *et al*., (2010) also reported improvement in yield attributes of

Table 1. Effect of nitrogen levels and kharif intercropping systems on growth and yield attributes of succeeding wheat

Treatment	Plant height (cm)		Tiller/mrl (No.)		Grains/spike (No.)		1000 grain wt. (g)	
	2011	2012	2011	2012	2011	2012	2011	2012
Nitrogen levels								
75% of RD of N	82.90	81.80	94.60	95.3	38	39	38.24	39.13
100% of RD of N	91.78	94.60	107.3	108.4	45	46	40.29	40.50
125% of RD of N	94.34	95.20	108.5	110.6	47	47	41.20	41.38
SEm±	0.89	0.24	0.43	0.8	0.74	0.3	0.4	0.39
CD at 5%	2.61	0.70	1.3	2.4	2.30	1.03	1.10	1.23
Intercropping systems								
Pigeon pea sole (45 cm)	93.68	94.06	108.7	110.3	44	46	40.20	40.51
Pearlmillet sole (45 cm)	86.18	86.07	93.2	95.4	42	42	39.96	39.86
Greengram sole (30 cm)	94.63	95.66	109.1	111.2	44	45	40.02	40.23
Pigeon pea–Paired row (30:60 cm)	93.53	94.08	108.9	109.3	44	44	40.56	39.24
Pigeon pea (75 cm)+Pearlmillet (1:1)	83.86	85.16	96.7	97.6	42	42	39.85	39.42
Pigeon pea (75 cm)+Pearlmillet (1:2)	83.28	84.29	97.1	98.5	42	42	39.25	39.48
Pigeon pea (75 cm)+Greengram (1:1)	92.17	94.00	108.7	109.4	44	45	40.55	40.61
Pigeon pea (75 cm)+Greengram (1:2)	93.71	92.17	108.9	110.1	45	46	40.28	40.49
Pigeon pea (90 cm)+Pearlmillet (1:1)	84.24	85.64	97.1	98.7	43	43	39.67	39.74
Pigeon pea (90 cm)+Pearlmillet (1:2)	84.13	86.16	97.5	99.0	43	43	39.62	39.89
Pigeon pea (90 cm)+Greengram (1:1)	93.12	94.08	107.4	108.4	43	45	39.08	40.02
Pigeon pea (90 cm)+Greengram (1:2)	93.39	95.09	108.1	109.3	44	46	40.07	40.56
SEm±	1.69	1.80	2.9	2.4	1.4	1.50	0.36	0.45
CD at 5%	4.91	5.20	8.7	7.2	NS	NS	NS	NS

Table 2. Effect of nitrogen levels and kharif intercropping systems on yield and harvest index of succeeding wheat

Treatment	Grain yield (kg/ha)		Straw yield (kg/ha)		Biological yield (kg/ha)		HI (%)	
	2011	2012	2011	2012	2011	2012	2011	2012
Nitrogen levels								
75% of RD of N	4247	4256	6810	7057	11057	11313	38.41	37.62
100% of RD of N	4403	4417	7228	7240	11631	11657	37.86	37.89
125% of RD of N	4521	4535	7369	7461	11890	11996	38.02	37.80
SEm±	42	4535	51	78	124	112	0.21	0.11
CD at 5%	120	126	152	225	368	335	NS	NS
Intercropping systems								
Pigeon pea sole (45 cm)	4451	4468	7564	7378	12015	11846	37.57	37.72
Pearlmillet sole (45 cm)	4135	4245	6416	6959	10551	11204	39.19	37.89
Greengram sole (30 cm)	4590	4507	7816	7431	12406	11938	37.00	37.75
Pigeon pea–Paired row (30:60 cm)	4524	4436	7255	7281	11779	11717	38.41	37.86
Pigeon pea (75 cm)+Pearlmillet (1:1)	4226	4234	6782	7153	11008	11387	38.39	37.18
Pigeon pea (75 cm)+Pearlmillet (1:2)	4200	4208	6646	7142	10846	11350	38.72	37.07
Pigeon pea (75 cm)+Greengram (1:1)	4540	4558	7303	7333	11843	11891	38.33	38.33
Pigeon pea (75 cm)+Greengram (1:2)	4556	4562	7626	7429	12182	11991	37.40	38.05
Pigeon pea (90 cm)+Pearlmillet (1:1)	4264	4277	6971	7196	11235	11473	37.95	37.28
Pigeon pea (90 cm)+Pearlmillet (1:2)	4240	4249	6831	7189	11071	11438	38.30	37.15
Pigeon pea (90 cm)+Greengram (1:1)	4424	4536	7128	7215	11552	11751	38.30	38.60
Pigeon pea (90 cm)+Greengram (1:2)	4434	4547	7284	7329	11718	11876	37.84	38.29
SEm±	76	62	122	83	72	94	0.74	0.51
CD at 5%	211	179	352	249	209	273	NS	NS

wheat when succeeded by greengram.

Yield and harvest index of wheat

Maximum grain yield of wheat was recorded at 125% of RD of nitrogen during 2011 and 2012; however, it was statistically at par with 100% RDN. 75% RDN produce significantly lower wheat grain, straw and biological yield as compared to 100% RDN (Table 2).

Grain, straw and biological yield of wheat sown after different intercropping system with the pigeon pea varied significantly. Grain yield of wheat was recorded maximum from after sole greengram at 30 cm or in combination with pigeon pea at 75 cm and 90 cm row spacing in one or two rows. Wheat grain yield was significantly lower when succeeded in pearlmillet intercrop treatments as compared to greengram intercrop; however, no significant variation in wheat was recorded when succeeded with 1:1 or 1:2 intercropping system of *kharif* season irrespective of pigeon pea row spacing during both years of study. Different row spacing and number of crops of intercropping *kharif* failed to influence the wheat grain yield, however, pearlmillet taken as intercropping in pigeon pea irrespective of number of rows and spacing of pigeon pea reduced the grain yield of succeeding wheat crop as compared to pigeon pea+greengram intercropping system significantly which might be due to the fact that more nutrients were removed by pearlmillet, whereas, greengram provided more nitrogen to wheat being a legume crop. The positive effect of legume as preceding crop in the rotation has also been reported by Ghanshyam *et al.*, 2010. Similar straw and biological yield of the wheat was found higher when the crop was taken after pigeon pea+greengram intercropping system as compared to pigeon pea+pearlmillet intercropping system.The different nitrogen levels and intercropping system failed to produce any significant variation in harvest index (%) of wheat followed by different intercropping systems tested during *kharif* season. The results are conferred with the Shirazi *et al*. (2014), Pardhan *et al*. (2014) and Jat *et al*. (2014).

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Bioefficacy of clodinafop 24% EC against grassy weeds in wheat (*Triticum aestivum* L.) and its residual carry over effect on succeeding crop

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ABSTRACT

An experiment was conducted during *Rabi* season of 2011-12 and 2012-13 at Hisar (Haryana) to evaluate the comparative efficacy of clodinafop 24% EC applied at different rates in wheat. The experimental field was infested with *Phalaris minor and Avena ludoviciana* during both the years of study. The results of study revealed that application of clodinafop 24% EC at 120 g/ha or at 70 g/ha recorded with significantly lower weed density, weed dry weight and weed index. Clodinafop 24% EC at 70 g/ha and 120 g/ha were most effective against grassy weeds with highest WCE of 98.6% and 97.2%, respectively observed at 30 DAT and 60 DAT. Significant variation in wheat yield and yield attributes was recorded due to the application of clodinafop 24% EC at different doses as compared with weedy check. clodinafop 24% EC at 70 g/ha found with highest grain yield with increase of 18.6% over weedy check and decrease of 3.1% over weed free and it was closely followed by clodinafop 24% EC applied at 120 g/ha. Residues of clodinafop 24 % EC applied in wheat even at twice the recommended dose, did not cause any adverse effect on crop growth and germination of succeeding sorghum crop.

Key words : Clodinafop, *Phalaris minor, Avena ludoviciana,* WCE, weed density, wheat, persistence

Wheat (*Triticum aestivum* L. *emend.*) is most important winter season cereal crop and is the backbone of food security in India. It is grown under diverse agro-climatic conditions on 29.65 m ha area in India with a production of 92.46 mt during 2012-13 (Anonymous, 2013). Despite the significant increase in wheat yield since the beginning of the green revolution, there are still management and environmental causes underlying weed problems. Among several constraints of wheat production, Weed infestation is one of the major constraints in achieving potential yield of wheat. It suffers from severe weed competition which reduces its yield to the tune of 25-55% (Singh *et al*. 2013) or even more, if not managed effectively. Cultivation of semi-dwarf input responsive wheat cultivars with slow initial growth, provide favourable environment for weeds. Generally, both grass and broad-leaf weeds infest wheat. Among grassy weeds, little seed canary grass (*Phalaris minor*) and wild oat (*Avena ludoviciana*) are major troublesome weeds under irrigated conditions in wheat crop. The higher cost and less efficacy of manual weeding in wheat made chemical weed control popular. Clodinafop in different concentrations is being used widely by wheat grower for control of grasses in north western Indian plains (Chhokar *et al.* 2013) but clodinafop 24% EC for grassy weeds control have not been evaluated. Clodinafop-propargyl interact with and inhibit the enzyme, acetyl co-enzyme A carboxylase (ACCase), which is essential for the production of lipids (fatty acids) needed for plant growth. Selectivity is based on the difference in the rate of herbicide breakdown in the crop versus the weeds. Clodinafop-propargyl converts from the ester form to the active acid and then to biologically inactive compounds (Hamada *et al.*, 2013). The aim of the present study was to evaluate the effect of Clodinafop 24% EC at different doses on grassy weeds in wheat crop, on the yield and yield attributes of wheat crop as well as residual effect on succeeding rice crop.

MATERIALS AND METHODS

A field experiment was conducted during winter (*Rabi*) season at agronomy research area of CCS Haryana Agricultural University, Hisar, Haryana, India ($29^0 10^0$N latitude, $75^0 46^0$E longitude and 215.2 M altitude) during

2011-12 and 2012-13 in randomized block design, replicated thrice with ten treatment combinations. Hisar has a semi-arid and sub-tropical climate with hot, dry and desiccating winds during summer and severe cold during winter season. The mean maximum, minimum temperature and total rainfall during crop season (November- April) were 25.8ºC, 9.2ºC, 47.7 mm and 25.1ºC, 9.6ºC, 114.6 mm respectively in 2011-12 and 2012-13. The soil of the field was sandy loam in texture, slightly alkaline in pH (8.2), low in organic carbon (0.32%), poor in available nitrogen (145 kg/ha) and medium in available phosphorus (12 kg/ha) and rich in available potassium (148.5 kg/ha). The crop was raised as per recommended package of practices of wheat for Haryana state. The wheat variety 'PBW 343' was sown on 10 December with the help of seed cum fertilizer drill at 18 cm row spacing using 125 kg seed/ha in a plot size of 9.5 x 2.5 m. All the herbicidal treatments were implied at 35 DAS with the help of knap sack sprayer fitted with flat fan nozzle using a spray volume of 500 liters/ha. Urea, diammonium phosphate and zinc sulphate were used as sources of nitrogen, phosphorus and zinc, respectively to supply the recommended dose of N (150 kg/ha), P_2O_5(60 kg/ha) and $ZnSO_4$ (25 kg/ha). Half nitrogen was applied basal at the time of sowing, whereas remaining nitrogen was top dressed at the time of first irrigation. Five irrigations in 2011-12 and four irrigations in 2012-13 were given at critical growth stages of crop and 6cm water were applied per irrigation. The data on density and dry weight of weeds was recorded at 30 and 60 DAT (days after treatment) by randomly placing two quadrates (0.5 x 0.5 m) per plot and computed to per square meter. Total number of weeds falling within the quadrate was counted-category wise in each plot and collected for dry matter accumulation. The dry weight of weeds was recorded by sun drying the counted weeds from each plot and then keeping them in oven at 70^0 C till constant weight was achieved. The dried samples were weighed and expressed in g/m^2. Weed control efficiency and weed index were calculated using standard formula. Data on yield contributing characters, and grain yield at harvest were studied for both the years. All the data were subjected to analyses with standard statistical procedure. Since, similar trend was noticed during both the years, pooling was done over the years. Where the F- test was significantly (at 5% level of significance) the least significant difference was used to compare the means at P=0.05. The data on number of weeds were subjected to square root transformation $\sqrt{X+0.5}$ before statistical analysis. Residual effect of these herbicides applied in wheat was studied through bioassay studies by planting sorghum var. SSG-Hara chara in the same plots by giving slight disking without disturbing the original layout. Data on plant population, plant height and green fodder yield was recorded 30 days after planting sorghum.

RESULTS AND DISCUSSION

Effect on weeds

All the herbicidal treatments significantly reduced the weed density and dry weight compared to weedy check during both the years (Table 1). However, most of the treatments could reach the level of weed free check in case of weed density and weed dry weight at both the stages of observation except Clodinafop 24% EC applied at 120 g/ha regarding weed density of *A. ludoviciana* observed at 30 and 60 DAT. Weed problem was more during 2012-13 as compared to 2011-12. Among all the treatments Clodinafop 24% EC applied at 120 g/ha proved superior in the control of *P. minor* and *A. ludoviciana*. The data revealed that Clodinafop 24% EC 120 g/ha recorded significantly the lowest density of *P. minor* and *A. ludoviciana* with a reduction of 79.7 and 64.1 percent, respectively over the weedy check at 30 days after treatment (DAT) and it was at par to all treatments except Clodinafop 24% EC 50 g/ha (Table 1). Similar trend of results were also observed at 60 DAT. Increasing trend in dry weight accumulation of weeds was observed with increase in plant age. As compared to weedy check, the maximum reduction in weed dry weight at 30 and 60 DAT was observed with Clodinafop 24% EC 120 g/ha by 75.5 and 81.3 percent ,respectively and it was statistically lower than other treatments except Clodinafop 24% EC 70 g/ha at both the stages of observation. The weed control efficiency (WCE) among the different treatments ranged from 76.6 to 98.6% at 30 DAT and 76.4 to 97.2% at 60 DAT (Table 1).The efficacy of different treatments estimated on the basis of weed biomass indicated that at 30 DAT Clodinafop 24% EC 70 g/ha was most effective against grassy weeds with WCE of 98.6% closely followed by Clodinafop 24% EC 120 g/ha (96.9%). While at 60 DAT Clodinafop 24% EC 120 g/ha was found with highest WCE of 97.2% followed by Clodinafop 24% EC 70 g/ha (93.6%). The highest visual weed control and lowest weed

Table 1. Effect of clodinafop 24% EC on density, dry weight and weed control efficiency (WCE) of weeds at 30 and 60 days after treatment (average of two years)

Treatment	Dose (g/ha)	Density (No./m^2) at 30 DAT				Dry wt. of grassy weeds (g/m^2)		WCE (%)	
		P. minor		*Avena ludoviciana*					
		30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT
Clodinafop 24% EC	50	1.78 (2.3)	1.94(2.8)	1.68 (1.9)	1.52(1.5)	3.29(10.9)	4.07(16.6)	76.6	76.45
Clodinafop 24% EC	60	1.38 (1)	1.39(1.0)	1.34(1.0)	1.39(1.0)	2.49(2.9)	2.97(8.2)	87.6	88.35
Clodinafop 24% EC	70	1.29 (0.8)	1.29(0.7)	1.09(0)	1.29(0.7)	1.21(0.6)	2.14(4.4)	98.65	93.6
Clodinafop 24% EC	120	1.09 (0.3)	1.19(0.5)	1.09(0)	1(0)	1.62(1.8)	1.57(1.9)	96.9	97.2
Clodinafop 15 WP	60	1.18 (1.2)	1.53(1.5)	1.49(1.7)	1.25(0.7)	2.28(5.0)	2.77(8.7)	89.5	87.45
Weed free	-	1.0(0)	1(0)	1.09(0)	1(0)	1(0)	1(0)	100	100
Weedy check	-	5.38(28.5)	5.4(27.7)	3.04(8.0)	3.41(10.7)	6.62(43.2)	8.39(69.8)	0	0
CD at 5 %		0.59	0.49	0.56	0.48	0.61	1.18	-	-

Transformed values ($\sqrt{x+1}$), original values are given in parenthesis DAT: Days after treatment.
Figures in parentheses are original values.

Table 2. Visual weed control, weed index, yield attributes and grain yield of wheat as affected by clodinafop 24 % EC (average of two years)

Treatment	Dose (g/ha)	Visual weed control (%)	WI (%)	No .of effective tillers/m^2	No. of grains/ear head	Test wt. (g)	Grain yield (kg/ha)
Clodinafop 24% EC	50	77.1	6.67	381	45.5	38.05	4337.5
Clodinafop 24% EC	60	83.5	4.84	384.5	46.5	37.65	4422.0
Clodinafop 24% EC	70	92.15	3.09	389.5	47.5	37.75	4503.5
Clodinafop 24% EC	120	92.75	3.34	389.5	46.5	37.5	4490.0
Clodinafop 15 WP	60	81.85	4.98	384	46.5	37.7	4416.0
Weed free	-	100	0.00	392.5	47.5	37.9	4647.5
Weedy check	-	0	18.31	361.5	44.5	37.7	3796.0
CD at 5%		4.785	212.50	7.2	2	NS	212.5

index were recorded with Clodinafop 24% EC applied at120 g/ha and at 70 g/ha (Table 2).

Effect on crop yield and yield attributes

All the treatments showed significantly higher values of effective tillers/m^2 and number of grains/ earhead over unweeded check (Table 2); however they were not at par with weed free regarding effective tillers/ m2, except Clodinafop 24% EC applied at 120 g/ha and at 70 g/ha. The positive effect of weed control treatments on test weight of wheat seed was observed over the weedy check; however non significant differences were observed among treatments. Data given in Table 2 revealed that all weed control treatments significantly increased wheat grain yield as compared to weedy check. Highest grain yield was observed with weed free which was statistically at par with Clodinafop 24% EC applied at 120 g/ha and at 70 g/ha. Clodinafop 24% EC at 70 g/ha found with highest grain yield with increase of 18.6% over weedy check and decrease of 3.1% over weed free treatment and it was closely followed by Clodinafop 24% EC applied at 120 g/ha. The evaluation of weed dry weight at 30 DAT and 60 DAT of the different treatments and the regression of yield on it revealed that linear equations $Y= -0.007x+33.12$ ($R^2=0.97$) and $Y= -0.009x+42.51$ ($R^2=0.98$) were fitted to be the best with their coefficient of determination, respectively (Fig.1(a) and Fig.1(b)). Similarly, weed control efficiency at 30 DAT and 60 DAT of the different treatments and the regression of yield on it revealed that linear equations $Y= 0.128x- 481.9$ ($R^2=0.96$) and $Y= 0.126x- 476.2$ ($R^2=0.97$) were fitted to be the best with their coefficient of determination, respectively (Fig.2(a) and Fig.2(b)). Increase in weed dry weight resulted in decrease in grain yield of wheat,

Table 3. Residual effect of clodinafop 24% EC applied in wheat on succeeding sorghum crop at 30 DAS (average of two years)

Treatment	Dose (g/ha)	No. of plants/ m^2	Plant height (cms)	Green fodder yield (q/ha)
Clodinafop 24% EC	50	21	124	387
Clodinafop 24% EC	60	21.5	123	390
Clodinafop 24% EC	70	20	120	386
Clodinafop 24% EC	120	22.2	124	389
Clodinafop 15 WP	60	21	123	388
Weed free	-	23	123	386
Weedy check	-	22.4	122	384
CD at 5 %		NS	NS	NS

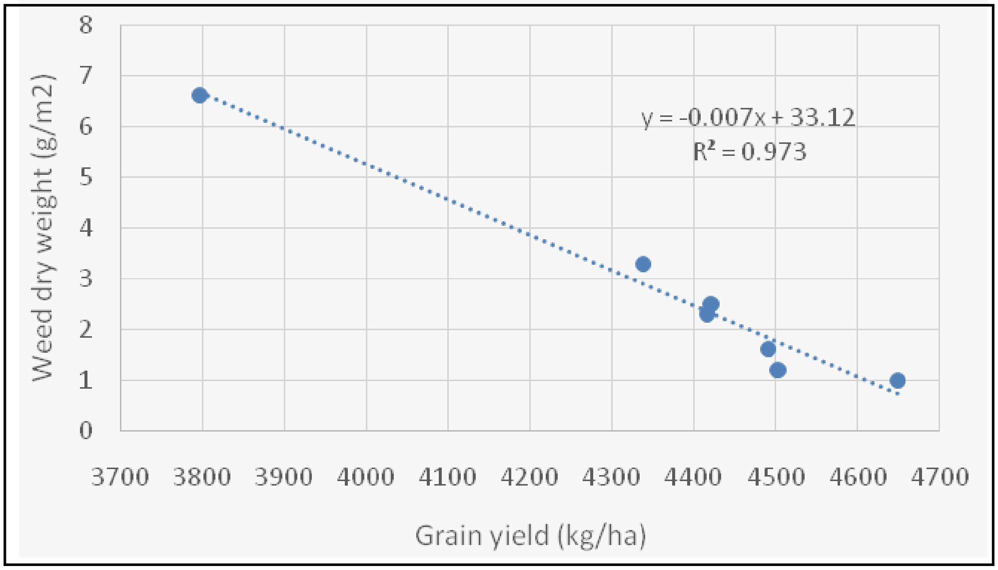

Fig. 1(a). Relationship between total weed dry weight at 30 DAT and grain yield.

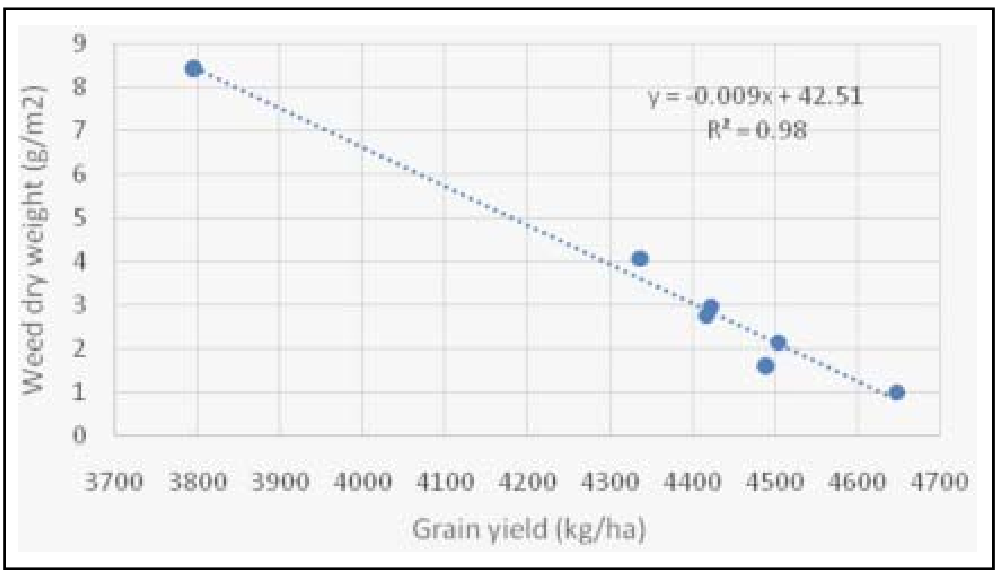

Fig. 1(b). Relationship between total weed dry weight at 60 DAT and grain yield.

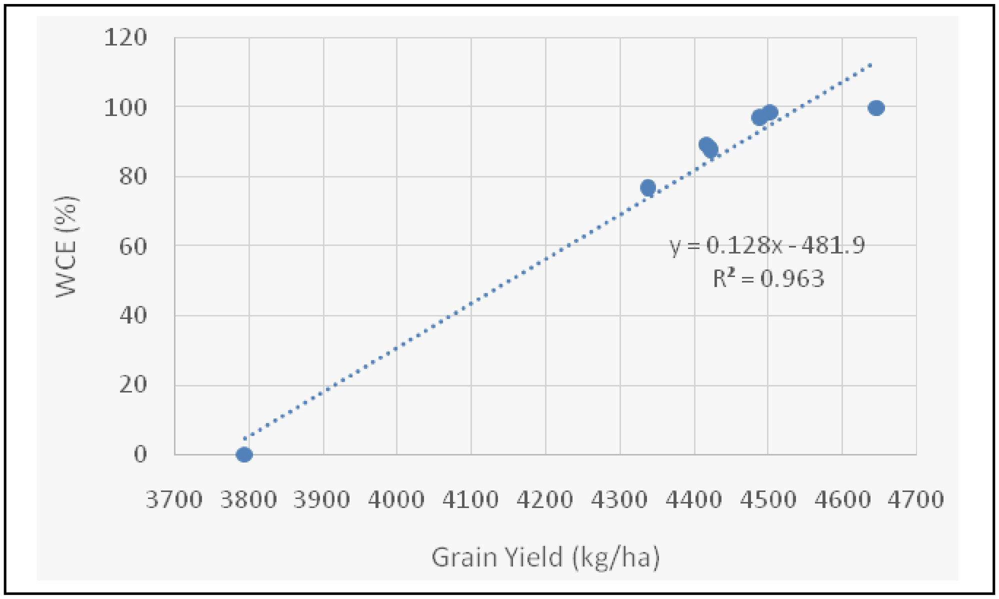

Fig. 2(a). Relationship between WCE at 30 DAT and grain yield.

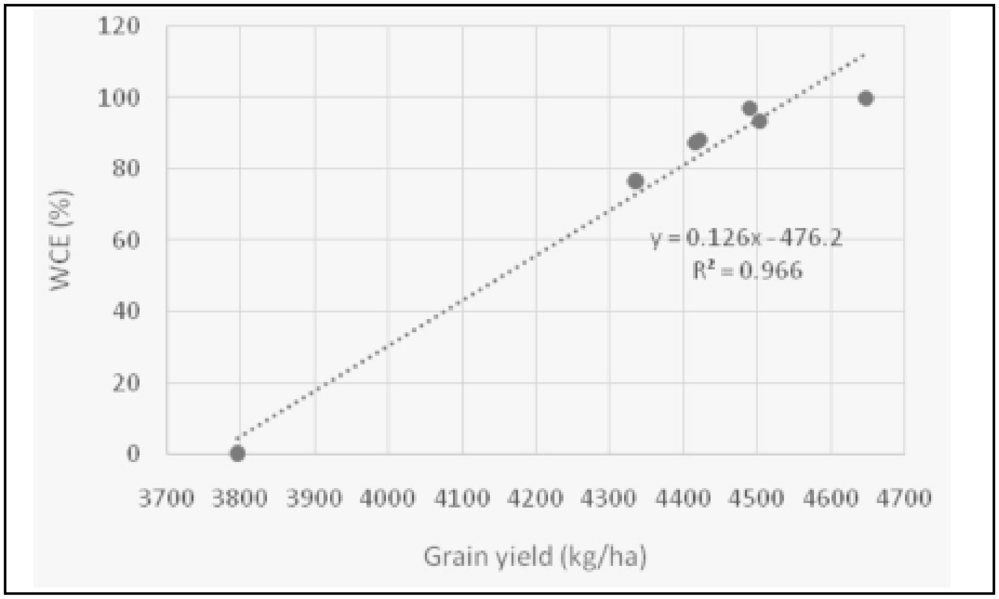

Fig. 2(b). Relationship between WCE at 60 DAT and grain yield.

while increase in weed control efficiency was resulted in increase in wheat grain yield at both 30 and 60 DAT stage of observation. These results were in conformity with the finding of Singh *et al*. (2013).

Residual effect of Clodinafop 24 % EC applied in wheat on the succeeding sorghum crop:

Residues of clodinafop 24% EC applied in wheat even at twice the recommended dose, did not cause any adverse effect on crop growth and germination of succeeding sorghum crop (Table3). Plant height of sorghum, no. of plants /m^2 and green fodder yield was statistically similar in clodinafop treated plots as well as untreated control.

So, it can be concluded that bioefficacy of "Clodinafop 24 % EC " formulation of clodinafop at 60 g/ha is as good as recommended formulation clodinafop

15 WP and sorghum can safely be grown after its application in wheat.

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Comparative performance of direct and transplanted Indian mustard *(Brassica juncea)* and rapeseed (*Brassica napus*) for nitrogen and water expense efficiency

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ABSTRACT

A field experiment was conducted during *rabi* 2004-05 to 2008-09 at Research Farm of the Punjab Agricultural University Regional Station, Bathinda on sandy loam soil conditions to study the response of sowing methods, age of seedling and nitrogen levels on Indian mustard and rapeseed mustard. The experiment was laid out in split-split plot with three methods of sowing *viz.*, Direct sowing (DS),transplanting of 30 days old nursery (T_{30}), transplanting of 45 days old nursery (T_{45}) as main plot treatments, two varieties of Indian mustard, PBR-91 and rapeseed,GSC-5 each in sub plots and three nitrogen levels, 75 % of recommended dose of N (N_1),100 % of recommended dose of N i.e. 100 kg N/ha (N_2) and 125 % of recommended dose of N (N_3) in sub sub plots with three replications. The results revealed that both the varieties performed better under direct sown conditions, however, PBR 91 registered 13.2% significantly higher grain yield than GSC5 under direct sowing. Among the age of seedlings, transplanting of 30 days old nursery gave significantly higher seed yield than 45 days old nursery under all levels of nitrogen. Variety GSC 5 (rapeseed) performed better than PBR 91 variety of Indian mustard under all nitrogen levels. Among yield attributing characters, the plant height was significantly maximum in direct sowing followed by transplanting of 30 days old nursery and minimum in 45 days old transplantation. The variety PBR 91 showed 19 % increase in plant height than GSC-5. The seeds per siliqua were significantly higher under direct sown crop and GSC-5 variety. Maximum water expense efficiency (WEE) was found in direct sown crop followed by T_{30} and T_{45} treatments. The WEE was higher in GSC-5 in N_1 and N_2 levels, whereas, under N_3 level maximum WEE was recorded in PBR-91 variety. There was lesser difference in WEE of various N levels.

Key words : Indian mustard, rapeseed, sowing methods, nitrogen levels, yield, water expense efficiency

INTRODUCTION

The demand of oilseeds is expected to increase 58 m.t. by the year 2020, wherein the share of rapeseed-mustard will be around 24.2 m. t. (Bartaria *et al*., 2002). But, unfortunately the area under oilseeds in Punjab is decreasing day by day. Under late sown conditions after the harvest of cotton crop, the sowing gets delayed and results lower yields of oilseeds. Oilseed rape (*Brassica napus*) has been adopted by farmers of the region to replace wheat especially under the area giving lower yields of wheat owing to late sowing. The other favorable feature of the *B.napus* is its ability to grow by transplanting, after raising nursery in the other field. The transplanted oilseed rape gave significantly higher seed yield than direct seeding under late sown conditions (Gupta, 1994). Plant breeding efforts in *B. napus* have resulted in improvements in the fatty acid composition of the oil (reduction of erucic acid) and a marked reduction in the level of glucosinolates have made it world's third most important vegetable oil after soybean and palm oil (Downey and Rimmer, 1993). Thus, a study was conducted to evaluate the comparative performance of Indian mustard *(Brassica juncea)* and rapeseed (*B. napus*) under various nitrogen levels and transplanting of seedlings on seed yield and water expense efficiency.

MATERIAL AND METHODS

A 5-year field study was conducted at Research Farm of the Punjab Agricultural University Regional Station, Bathinda during *rabi* 2004-05 to 2008-09 on sandy loam soil conditions. The organic carbon content, pH, $CaCO_3$ were 0.25%, was 8.45 and 4.49%, respectively. The available phosphorus and potash in the surface layer were 11.7 and 342 kg ha^{-1}, respectively.

The experiment was laid out in split-split plot with three methods of sowing *viz.*, Direct sowing (DS), transplanting of 30 days old nursery (T_{30}), transplanting of 45 days old nursery (T_{45}) as main plot treatments, two varieties of Indian mustard, PBR-91 and rapeseed, GSC-5 each in sub plots and three nitrogen levels, 75% of recommended dose of N (N_1),100 % of recommended dose of N *i.e.* 100 kg N/ha (N_2) and 125 % of recommended dose of N (N_3) in sub sub plots with three replications.

RESULTS AND DISCUSSION

The results revealed that both the varieties performed better under direct sown conditions (Table 1).Variety PBR 91 registered 13.2% significantly higher grain yield than GSC5 under direct sowing. The reason for lesser yields under transplanted crop than direct sown crop may be as transplanted crop may pass through variant climatic conditions as compared to the direct seeded crop. When Compared seedlings age, the transplanting of 30 days old nursery gave significantly higher seed yield than 45 days old nursery under all levels of nitrogen. The transplanting of seedlings of 30 days old nursery gave 15.4% more grain yield than transplanting of 45 days old seedlings. Singh and Singh, (2012) also reported optimum age of transplanting nursery for *gobhi sarson* as 30 days as it yields higher than 45 days old seedlings. Sardana (2007) also reported seed yield declination with delay in transplanting. Variety GSC 5 (rapeseed) performed better than PBR 91 variety of Indian mustard under all nitrogen levels. The different doses of nitrogen had shown non significant effects on age of seedlings. There was a marginal increase in crop yields from 75 % RDN to 100% RDN, which further decreased with increase in nitrogen level (125 % RDN), but the differences were non significant. Among yield attributing characters, the plant height was significantly maximum (Table.2) in direct sowing followed by transplanting of 30 days old nursery and minimum in 45 days old transplantation. The variety PBR 91 showed 19 % increase in plant height than GSC-5. This may be due to interactive effect of genotype with the environment during that particular stage. Thakur *et al* (2005) also reported that plant height of different genotypes was different because of their genetic constitution. The seeds per siliqua were significantly higher under direct sown crop and GSC-5 variety. Different treatments had non significant effect on primary and secondary branches.

Table 1. Effect of different methods of sowing and doses of nitrogen on grain yield (kg/ha) and water expense efficiency of Indian mustard and rapeseed mustard (Pooled mean of 5 years)

Varieties	Grain yield (kg/ha)				Water expense efficiency (kg/ha-cm)			
	DS	T30	T45	Mean	DS	T30	T45	Mean
				N_1				
PBR-91	1731.1	1139.0	931.7	1269.3	44.78	27.67	22.23	31.56
GSC-5	1475.3	1221.7	1134.8	1277.2	36.45	29.08	33.42	32.98
Mean	1606.3	1180.0	1033.2	1273.2	40.62	28.35	27.27	32.08
				N_2				
PBR-91	1785.9	1123.8	893.4	1267.7	45.98	28.92	20.95	31.95
GSC-5	1556.8	1236.4	1112.5	1301.9	39.39	30.90	30.33	33.54
Mean	1671.3	1180.2	1002.9	1284.8	42.69	29.88	25.48	32.60
	N_3							
PBR-91	1778.1	1120.1	898.1	1265.4	47.30	27.82	28.14	34.42
GSC-5	1561.9	1239.6	1081.1	1294.7	39.35	30.20	29.36	32.97
Mean	1670.0	1179.8	989.6	1280.9	43.43	29.03	25.71	32.70
				Overall average				
PBR-91	1765.0	1127.6	907.7	1267.5	46.0	28.1	23.8	32.64
GSC-5	1531.3	1232.6	1109.5	1291.3	38.4	30.1	31.0	33.16
Mean	1649.0	1180.0	1008.6		42.2	29.1	26.2	

Seed yield CD (P=0.05) Varieties (A) = 143.2, Method of sowing (B) = 103.2, Nitrogen levels (C)=NS
Interaction : A X B=178.7, B X C=60.

Table 2. Effect of different methods of sowing and doses of nitrogen on yield attributes of Indian mustard and rapeseed mustard. (Pooled mean of 5 years)

Treatment	Plant height	Primary branches	Secondary branches	Siliqua (no.) per plant
		Method of sowing/Planting		
Direct sowing	167.1	4.3	13.8	264.0
T_{30}	148.6	4.7	14.3	250.4
T_{45}	129.7	4.3	10.4	241.8
CD (%)	14.2	NS	NS	13.2
		Varieties		
PBR-91	164.1	4.1	14.3	226.9
GSC-5	132.9	4.5	14.1	277.1
CD (%)	4.2	NS	NS	20.5
		Levels of nitrogen		
75 % RDN	148.5	4.36	14.76	254.5
100 % RDN	148.3	4.36	14.0	249.8
125 % RDN	148.7	4.58	13.7	251.9
CD (5%)	NS	NS	NS	NS

Table 3. Effect of different methods of sowing and doses of nitrogen on water expense components of Indian mustard and rapeseed mustard.(Pooled mean of 5 years)

Treatment	Profile water use	Irrigation water applied	Water expense
		Method of sowing/Planting	
Direct sowing	6.8	25.5	40.1
T_{30}	5.0	37.5	41.1
T_{45}	0.2	30.0	36.7
Mean	4.0	31	39.3
		Varieties	
PBR-91	2.34	32.5	39.1
GSC-5	2.58	32.5	39.5
Mean	2.46	32.5	39.3
		Levels of nitrogen	
75% RDN	2.42	29.0	39.4
100% RDN	2.56	29.0	39.5
125% RDN	2.22	29.0	39.5
Mean	2.40	29.0	39.5

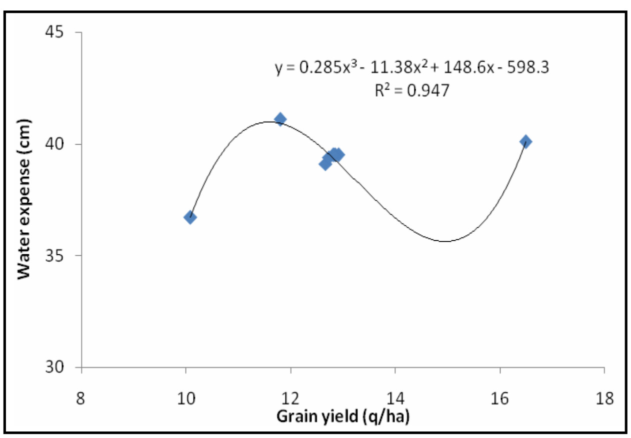

Fig. 1. Grain yield of raya and gobhi sarson in relation to water expense (Pooled mean of 5 years).

Among methods of planting, the irrigation water applied (Table 3) was maximum in T_{30} followed by T_{45} and lowest in direct sowing treatment. There was a spectacular increase in water expense efficiency (WEE) in the treatments with lower irrigation water expense (direct sowing). The strong association between water expense and grain yield (r=0.94) is depicted in fig1.The Irrigation water applied did not vary under both the varieties and nitrogen levels. Similar results were observed by Buttar *et al.* (2012) regarding nitrogen levels. Under interaction studies, the water expense efficiency was higher in GSC-5 in N_1 and N_2 levels, whereas, under N_3 levels maximum WEE was recorded in PBR-91 variety. There was lesser difference in WEE of various N levels.

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Interactive effect of phosphorus and sulphur on yield, quality and nutrients uptake by Indian mustard (*Brassica juncea L.*)

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ABSTRACT

Grain yield of mustard significantly increased from 7.98 to 9.22 and 10.79 q ha^{-1} with the application of 30 and 60 kg S ha^{-1}, respectively over no S. Application of 30 and 60 kg P_2O_5 ha^{-1} also increased the grain yield of mustard from 7.98 to 10.49 and 14.81 q ha^{-1}, respectively over no P. Consecutive use of 30 kg P_2O_5 + 30 kg S significantly increased the grain yield from 7.98 to 14.88 q ha^{-1} over control without P and S. Significantly and higher grain yield 17.27 q ha^{-1} was recorded with the application of 60 kg P_2O_5 + 60 kg S ha^{-1} over all other treatments. Stover yield of mustard also followed the similar trend and highest yield 44.10 q ha^{-1} was recorded with the combined application of 60 kg P_2O_5 + 60 kg S ha^{-1}. The maximum harvest index (HI) 28.99 % was recorded with the treatment having 30 kg P_2O_5 + 30 kg S ha^{-1} followed by 28.14 % with the application of 60 kg P_2O_5 + 60 kg S ha^{-1}. The highest oil content 38.03 %, oil yield 6.57 q ha^{-1} and protein content 21.37% was recorded with the application of 60 kg P_2O_5 + 60 kg S ha^{-1}. Application of S and P also increased the N, P and S uptake from 23.78 to 59.06, 2.27 to 7.24 and from 3.83 to 20 .55 kg ha^{-1}respectively with the application of 60 kg P_2O_5+60 kg S ha^{-1} over all other treatments. Highest N, P and S uptake by mustard stover 49.83, 8.56 and 15.57 ha^{-1}, respectively were also recorded with the application of 60 kg P_2O_5 + 60 kg S ha^{-1} over all other treatments.

Key words : Mustard, sulphur, phosphorus, grain, stover yield, harvest index, nutrient uptake, oil content and oil yield

INTRODUCTION

Oilseeds play a major role in Indian economy and there is a need to raise the oilseed production to bridge the large gap between the demand and supply of edible oils. Rapeseed-mustard shares about 28 % of total oilseed production in India, with area of 6.32 m ha and production of 6.12 m t. It is only second to groundnut among oilseeds. Commercially rapeseed-mustard are obtained from the genus *Brassica* belonging to the family Cruciferae. *Brassica* crops are destined to play an ever-increasing role in the supply of the world's food, feed and industrial needs in the next century (Verma and Baigh, 2012). Rapeseed-mustard seed is mainly used for the extraction of oil (Manmohan 2013). Seed meal obtained after oil extraction from the seed is used as an animal feed. It is a rich source of good quality proteins and can be utilized for production of value-added products like protein concentrate, baby food and biscuits after some processing. Presently, it is largely consumed as animal feed and also being exported to some extent (Chauhan and Kumar, 2011). Phosphorous plays a vital role as a structural component of cell constituent and metabolically active compounds *i.e.* chloroplasts, mitochondria, phytin, nucleic acid, protein, flavin nucleotides and several enzymes. It also plays a crucial role in growth and development of roots, tillers and grains, energy transformation and metabolic process of plants. Sulphur also takes place in the formation of chlorophyll, glucosides, glucosinolates and thiamine. It is involved in the activities of enzymes and improves crop yield, oil content in oil seeds and proteins in plant. Bharose *et al.* (2011) reported that, in recent years sulphur deficiency has been aggravated in the soil due to continuous crop- removal and use of sulphur and zinc free NPK fertilizers. Leaching and erosion losses also contribute to sulphur deficiencies.

In views of these problems an investigation was undertaken to investigate the interactive effect of phosphorus and sulphur on yield, quality and nutrients uptake by Indian mustard (*Brassica juncea L.*)

MATERIALS AND METHODS

A field experiment was carried out at the Research Farm of Amar Singh (P.G.) College, Lakhaoti, Bulandshahr (U.P.). Geographically Lakhaoti is located at 28.4^0 North Latitude and 77.28^0 East Longitude and an altitude of 207.3 m above the mean sea level. The experiment was conducted to study the interactive effect of phosphorus and sulphur on yield, quality and nutrients uptake by Indian mustard (*Brassica juncea L.*). Soil of the experimental field was well drained, sandy loam in texture, slightly alkaline in reaction (pH 7.6), having EC 0.30 dS m^{-1}, organic carbon 2.4 g kg^{-1} soil, available nitrogen 196 kg ha^{-1}, available phosphorus 9 kg ha^{-1}, potassium 242 kg ha^{-1} and available sulphur 17.92 kg ha^{-1}. Nine treatments (Table. 1) were maintained consisting of three levels of sulphur 0, 30 and 60 kg ha^{-1} and three levels of phosphorus 0, 30 and 60 kg ha^{-1}, materials and methods were laid out in randomized block design (RBD) and replicated thrice. Nitrogen, phosphorus and sulphur @ 120:60:60, respectively were supplied through urea, Di-ammonium phosphate and gypsum. Half dose of nitrogen and full doses of phosphorus and sulphur as basal were applied to each plot. The remaining half dose of N was applied at pre-flowering stage *i.e.* 45 DAS (days after sowing). Based on initial soil analysis potassium was not applied to the experimental plots. The variety of Indian mustard T-59 (Varuna) was used as test crop. All the agronomic practices were followed according to package of practices in mustard crop.

The data of grain and stover yield were recorded, when crop was harvested at maturity. The grain samples were taken and analyzed for oil content (Soxhlet's method, A.O.A.C., 1970). The grain and stover samples were analyzed for total nitrogen content (Kjeldahl's method, Jackson, 1973), phosphorus content (Vanadomolybdophosphoric yellow color method, Jackson, 1973) and sulphur content (Spectronic-20 at 420 nm); however protein content was calculated by multiplying nitrogen content of grain with a factor of 6.25 (Gupta *et al.* 1972) and oil yield was calculated with the help of oil content in grain. Soil samples were analyzed for pH (Glass electrode pH meter), EC (Conductivity bridge method), organic carbon (Walkley and Black's rapid titration method, Jackson 1973), available-N (Alkaline permanganate method, Subbiah and Asija 1956), available-P (Olsen's method, Olsen *et al.* 1954), available-K (Flame photometer, Chopra and Kanwar, 1991) and available-S (Turbidity method, Chesnin and Yien, 1951).

Table 1. Details of treatments

Treatments	Description
T_1	Control
T_2	No P_2O_5+30 kg Sulphur, ha^{-1}
T_3	No P_2O_5+60 kg Sulphur, ha^{-1}
T_4	30 kg P_2O_5+No Sulphur, ha^{-1}
T_5	30 kg P_2O_5+30 kg Sulphur, ha^{-1}
T_6	30 kg P_2O_5+60 kg Sulphur, ha^{-1}
T_7	60 kg P_2O_5+No Sulphur, ha^{-1}
T_8	60 kg P_2O_5+30 kg Sulphur, ha^{-1}
T_9	60 kg P_2O_5+60 kg Sulphur, ha^{-1}

RESULTS AND DISCUSSION

Crop yields

Data (Fig. 1) indicated that application of S and P increased the grain and stover yield significantly as compared to control. Grain yield of mustard significantly increased from 7.98 to 9.22 q ha^{-1} with the application of S 30 kg ha^{-1} and it further improved by 10.79 q ha^{-1} with the increasing S level *i.e.* 60 kg ha^{-1}. Likewise the application of P also increased the grain yield of mustard from 7.98 to 10.49 with the application of 30 kg P_2O_5 ha^{-1} and application of 60 kg P_2O_5 ha^{-1} further increased it to 14.81 q ha^{-1}. Consuctive use of 30 kg P_2O_5 + 30 kg S ha^{-1}, significantly increased the grain yield from 7.98 to 14.88 q ha^{-1}over control. Significantly and higher grain yield 17.27 q ha^{-1} was recorded with the application of 60 kg P_2O_5 + 60 kg S ha^{-1} followed by 16.87 q ha^{-1} with the treatment having 60 kg P_2O_5 + 30 kg S ha^{-1} over all other treatments. Stover yield of mustard too showed (Fig. 1) linear increase with increasing levels of P and S. Application of S and P alone or in combination significantly increased the stover yield of mustard with each successive increase in P and S level up to the highest dose *i.e.* 60 kg P_2O_5 + 60 kg S ha^{-1} and increase was from 23.93 to 44.10 q ha^{-1} over control. The results are similar with the findings of Singh and Singh (2003), Kumar and Yadav (2007), Khatkar *et al.* (2009), Yadav *et al.* (2010), Bharose *et al.* (2011), Paliwal and Singh (2014) and Yadav *et al.* (2014).

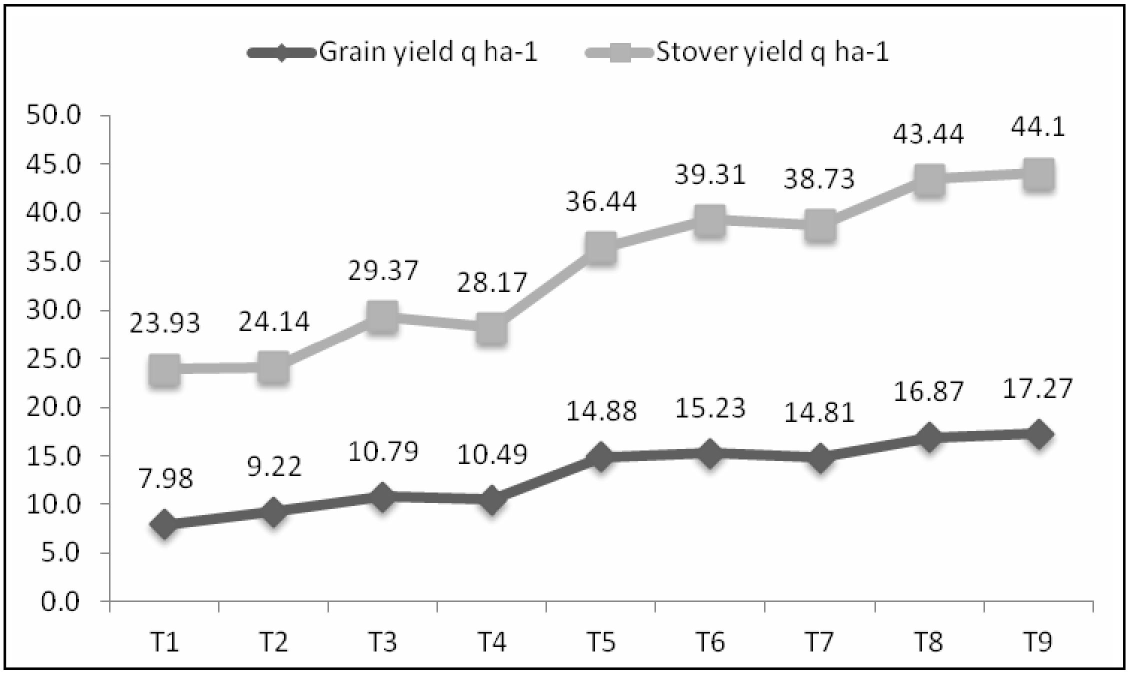

Fig. 1. Effect of P and S on grain yield and stover yield of Indian mustard (CD at 5%, grain = 2.75, stover = 5.10).

Harvest index

Data regarding harvest index (Fig. 2) indicated that application of S and P significantly increased the HI either alone or in combination. The maximum HI 28.99 % was recorded with the treatment having 30 kg P_2O_5 + 30 kg S ha^{-1} followed by 28.14 % with the application of 60 kg P_2O_5 + 60 kg S ha^{-1} and least 25.01 % with the control. The results are similar as reported by Singh *et al.* (2008).

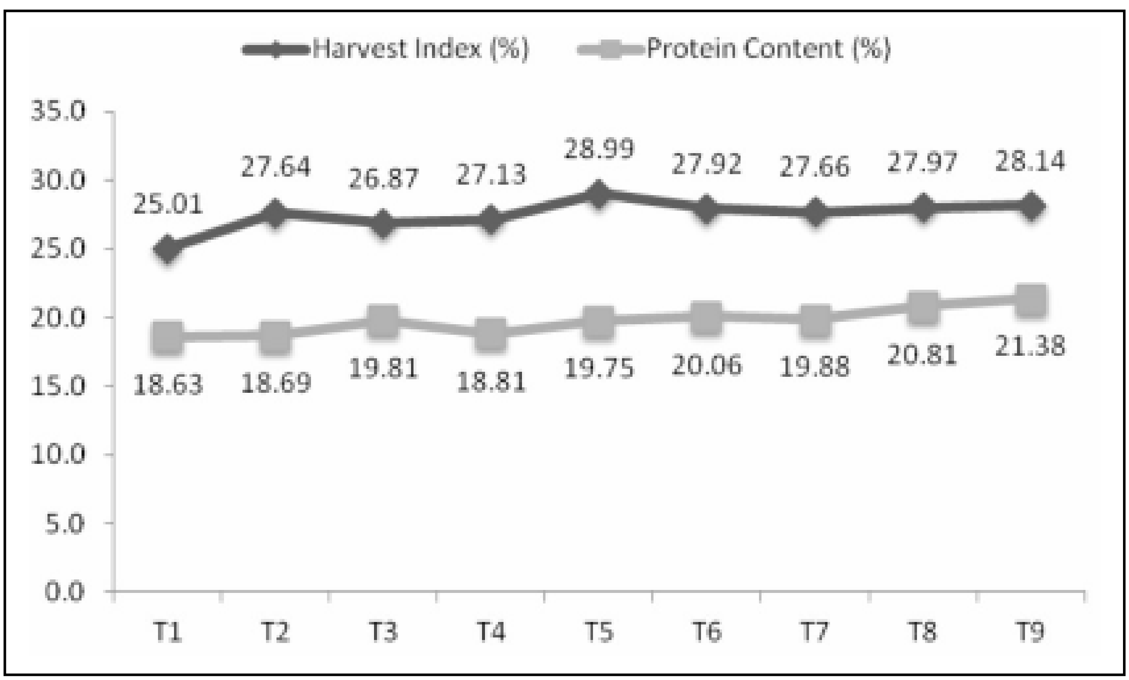

Fig. 2. Effect of P and S on harvest index and protein content of Indian mustard (CD at 5%, HI=2.64, protein content=0.82).

Protein content

Data regarding protein content (Fig. 2) indicated that S and P either alone or in combination increased protein content of mustard grain. The treatment containing 60 kg P_2O_5 + 60 kg S ha^{-1} registered highest 21.38 % followed by 20.81 % protein content with the application of 60 kg P_2O_5 + 30 kg S ha^{-1} as compared to 18.63 % with the control. Effects of Lower doses of either S or P were found similar to control for protein content in mustard grain. Similar results were reported by Singh *et al.* (2010), Bharose *et al.* (2011), Chauhan and Kumar (2011) and Paliwal and Singh (2014).

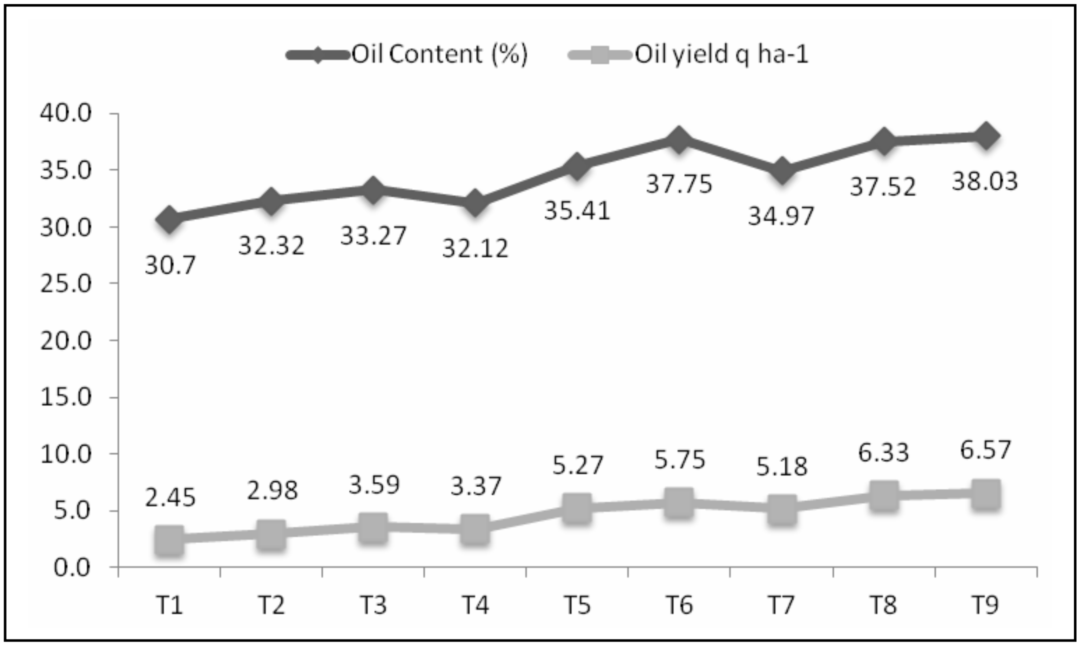

Fig. 3. Effect of P and S on oil content and oil yield of Indian mustard (CD at 5%, oil content=0.90, oil yield=NS).

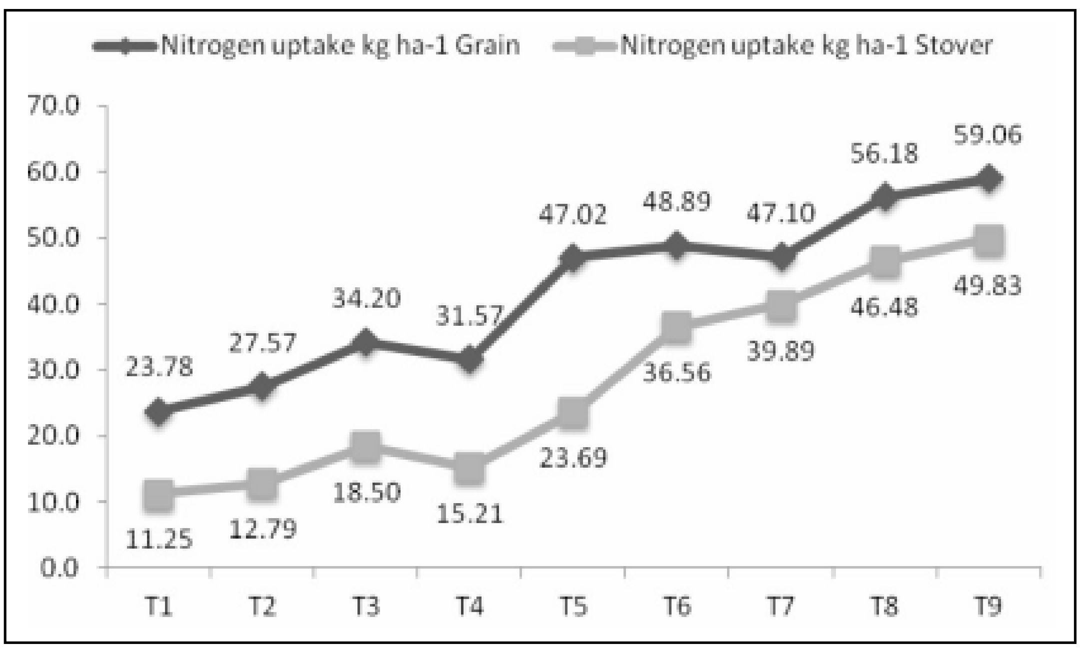

Fig. 4. Effect of P and S on nitrogen uptake by Indian mustard (CD at 5%, grain=6.72, stover=5.90).

Oil content and oil yield

It is evident from data in Fig. 3 that S at its both levels increased in grain oil content by 32.32 % and 33.27 % with the application of S 30 kg alone and S 60 kg ha^{-1}, respectively over control but application of 30 kg P_2O_5 ha^{-1} alone did not increase oil content. Combining of S and P together made a marked increase in grain oil content *i.e.* 35.41 % with the application of 30 kg P_2O_5 + 30 kg S ha^{-1} and 37.52 % by 60 kg P_2O_5 + 30 kg S ha^{-1} and highest 38.03 % oil content was recorded with the application of 60 kg P_2O_5 + 60 kg S ha^{-1}. The oil yield increased (Fig. 3) from 2.45 q ha^{-1} to 6.57 q ha^{-1} with 60 kg P_2O_5 + 60 kg S ha^{-1} over control closely followed by 6.33 q ha^{-1} with the application of 60 kg P_2O_5 + 30 kg S ha^{-1}.Similar results were reported by Singh *et al.* (2010), Pachauri *et al.* (2012), Paliwal and Singh (2014) and Yadav *et al.* (2014).

Nutrients uptake

Nitrogen : The uptake of N in grain increased largely (Fig. 4) with increasing levels of S and P when applied either alone or in combination. Lowest N uptake of 23.78 kg ha^{-1} was recorded with the control whereas a highest 59.06 kg ha^{-1} N uptake was observed with the treatment 60 kg P_2O_5 + 60 kg S ha^{-1} followed by 56.18 kg ha^{-1} with the application of 60 kg P_2O_5 and 30 kg S ha^{-1}. Stover of mustard also exhibited highest N uptake (49.83 kg ha^{-1}) with the application of 60 kg P_2O_5 + 60 kg S ha^{-1} as compared to 11.25 kg ha^{-1} with the control. Similar findings were reported by Jaggi and Sharma (1999), Rana *et al.* (2005), Singh and Pal (2011) and Pachauri *et al.* (2012).

Phosphorus : Application of S and P greatly increased the P uptake by mustard grain (Fig. 5). A low value of 2.27 kg ha^{-1} was registered with the treatment control but application of 30 kg P_2O_5 ha^{-1} raised it to 3.73 kg ha^{-1} and higher level of P_2O_5 @ 60 kg ha^{-1} improved it further to 6.15 kg ha^{-1}. The application of 60 kg P_2O_5 + 60 kg S ha^{-1} registered highest P uptake 7.24 kg ha^{-1} followed by 7.05 kg ha^{-1} with the application of 30 kg P_2O_5 + 60 kg S ha^{-1}. The P uptake by mustard stover also followed similar trend as that of P uptake by grain. The P uptake by stover increased with the increasing dose of S and P upto the level of 60 kg P_2O_5 + 60 kg S and increase was from 3.78 to 8.56 kg ha^{-1} over all other treatments. The results are closed with the findings of Rana *et al.* (2005), Yadav *et al*. (2010), Bharose *et al.* (2011) and Pachauri *et al*. (2012).

Sulphur : There was an improvement in S uptake (Fig. 6) of mustard grain due to application of increasing levels of S and P when applied alone or in combination. The highest S uptake 20.55 kg ha^{-1} was

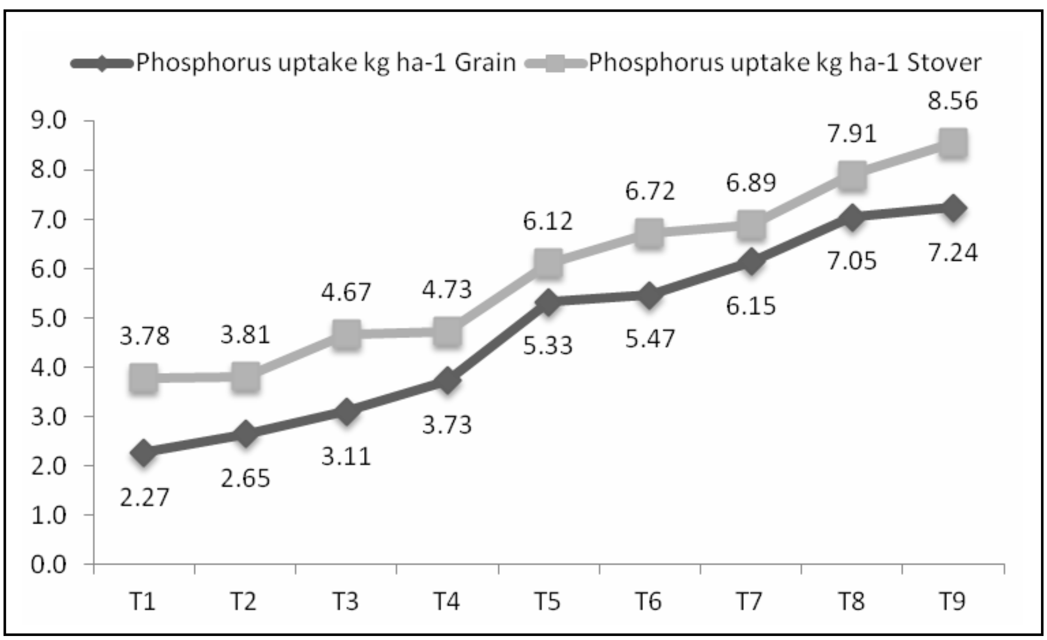

Fig. 5. Effect of P and S on phosphorus uptake by Indian mustard (CD at 5%, grain=0.88, stover=0.60).

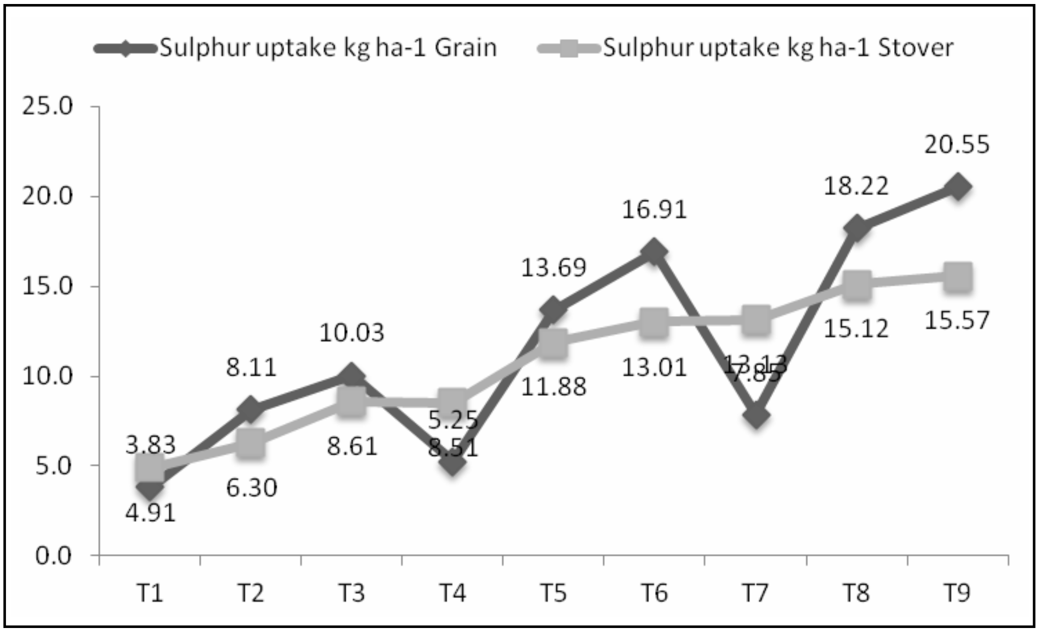

Fig. 6. Effect of P and S on sulphur uptake by Indian mustard (CD at 5%, grain = 2.34, stover = 1.68).

recorded with the application of 60 kg P_2O_5 + 60 kg S ha^{-1} followed by 18.22 kg ha^{-1} by 60 kg P_2O_5 + 30 kg S ha^{-1} as compared to 3.83 kg ha^{-1} with the control. The S uptake of stover showed (Fig. 6) similar trends and also depicted significant interaction effect of phosphorus and sulphur application on S content. The S uptake by stover increased with the increasing dose of S and P upto the level of 60 kg P_2O_5 + 60 kg S ha^{-1} and increase was from 3.83 to 15.57 kg ha^{-1} over control and all other treatments. The findings were in close conformity with Jaggi and Sharma (1999), Yadav *et al.* (2010), Singh and Pal (2011), Bharose *et al.* (2011) and Pachauri *et al*. (2012).

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Effect of nutrient management on growth and yield of cauliflower (*Brassica oleracea* var botrytis) inside low cost polyhouse

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ABSTRACT

Cauliflower is an important cash crop of Himachal Pradesh fetching reasonably high market price during off season. Keeping this in view the investigations entitled "Effect of nutrient management on growth and yield of cauliflower inside low cost polyhouse" were carried out at the research farm of the Department of Agricultural Engineering, CSKHPKV, Palampur (H.P) during *Rabi* seasons of 2005 and 2006. The study aimed to find out best combination of NPK as well as the effect of different NPK levels on growth, yield and yield contributing characters of cauliflower under low cost polyhouse. The experiments were laid out in RBD (factorial) with three replications. Results of the study revealed that application of 150% of recommended NPK without differing with 125% of NPK recorded significantly higher stalk length, leaves/ plant, curd size and weight than other levels of NPK.

Key words : Polyhouse, cauliflower, nutrient, NPK

INTRODUCTION

Cauliflower is an important cash crop of Himachal Pradesh fetching reasonably high market price. But the productivity of this crop is very low. Many reasons are assigned for its low productivity, one of which include low use of nutrients. At present, growing of cauliflower in our state/country is practiced in open field conditions. Cauliflower grown in open fields is exposed to various abiotic and biotic stresses and therefore, it is not possible to produce high quality cauliflower in terms of size and shape and free from pest and diseases as compared to cauliflower produced under protected environment in other countries. Therefore, it makes imperative to take up cauliflower cultivation under green house conditions particularly when production of cauliflower is for export purpose. Nutrient management is one of the most important practices for profitable cultivation of any vegetable crop. Recommendations on fertilizer application in cauliflower have also been made from different parts of the country with varying doses of different nutrients depending upon the soil fertility status under different regions. Keeping the above facts in view, the present investigation was undertaken during *rabi* seasons of 2005 and 2006 to ascertain the optimum dose of N P K for exploiting the yield potential of cauliflower.

MATERIAL AND METHODS

A field experiment was conducted inside low cost polyhouse at Research Farm, Department of Agricultural Engineering, CSK HPKV, Palampur situated at an elevation of 1,280 meters above mean sea level during *rabi* seasons of 2005 and 2006. Treatments comprising five combinations of N P K *viz.* F_1 (50% NPK), F_2 (75% NPK), F_3 (100% NPK i.e. 100 kg N/ha, 75 kg P/ha and 75 kg K/ha), F_4 (125% NPK) and F_5 (150% NPK) were compared in randomized block design with three replications. The soil of the experimental field was clay loam in texture having pH 5.4, high in organic carbon (9.48%), low in available nitrogen (247 kg N/ha) and phosphorus (8.5 kg p/ha) and medium in potassium 260 kg K/ha). One third of nitrogen and full dose of phosphorus and potassium were applied at the time of transplanting. Remaining nitrogen was applied in two equal splits at 30 and 60 days after transplanting (DAT). Rest of the management practices were in accordance with the recommended package of practices of the crop. The data were recorded on four randomly selected plants in each plot for stalk length (cm), leaves/ plant, curd size (cm), marketable curd weight (kg), gross curd weight (kg). The marketable curd yield was recorded on plot basis and was converted into kg/100m^2.

Table 1. Effect of NPK levels on growth, yield attributes and yield of cauliflower (Pooled data)

Treatment	Stalk length (cm)	Leaves/ plant (No.)	Curd size (cm)	Marketable curd weight (kg)	Gross curd weight (kg)	Curd yield (kg/100 m^2)
50% NPK	1.4	17.4	20.2	0.532	1.310	307.5
75% NPK	1.7	19.7	20.6	0.750	1.518	369.0
100% NPK	2.0	21.3	21.8	1.432	2.615	439.9
125% NPK	2.1	22.7	22.2	1.510	2.718	492.3
150% NPK	2.4	23.4	22.7	1.525	2.814	503.5
CD (P=0.05)	0.2	0.8	0.5	0.12	0.10	16.4

RESULTS AND DISCUSSION

Application of higher dose of NPK combination significantly influenced the yield of cauliflower (Table 1) during both the years. Amongst different levels of NPK, application of 150% of NPK without differing with 125% of NPK recorded significantly higher stalk length, leaves/ plant, curd size and weight than other levels of NPK. The higher level of nitrogen have a tendency to increase protein synthesis, which subsequently cause an increase in cell size and number leading to more stalk length and leaves/plant. Theses results are in conformity with those of Parmar and Sharma (2001). Increased fruit size and weight due to increased application of NPK (50% more of the recommended dose of NPK) may probably be due to increase in the sufficient amount of food material manufactured by the foliage. These effects culminated in increased fruit yield/100m^2 with increasing level of NPK. On an average, 50% more of the recommended dose of NPK recorded 63.7 % higher yield over 50% less than recommended dose of NPK. These results are in agreement with those of Kapoor *et al.* (2014).

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Effect of plastic mulching, planting methods and fertility levels on growth and productivity of potato (*Solanum tuberosum* L.)

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ABSTRACT

A field experiment was conducted during *Rabi* 2011-12 at the experimental farm of CSKHPKV, Palampur, Himachal Pradesh to study the effect of plastic mulching, planting methods and fertility levels on growth and yield of potato (*Solanum tuberosum* L.). The experiment was laid out in split plot design with three replications. The main plot consisted of three different mulching (black polyethylene mulch, transparent polyethylene mulch and no mulch) and two planting methods (ridge method and flat bed method) whereas sub plot had three fertility levels (75% NPK, 100% NPK and 125% NPK). Application of black polyethylene mulch resulted in highest tuber yield (316.6 q ha^{-1}) than transparent polyethylene and no mulch. Planting potato crop in ridge method gave higher tuber yield (289.2 q ha^{-1}) than flat bed method. Increase in graded fertility levels from 75% to 125% NPK improved growth characters, yield parameters, tuber yield consistently and significantly. Highest tuber yield (298.9 q ha^{-1}) was obtained with the application of 125% NPK. Quality parameters like starch content and graded yield of large sized tubers were found higher with black polyethylene mulch than no mulch. Present study also revealed that for higher tuber production, potato crop should be planted on ridges with black polyethylene mulch and 100% NPK or transparent polyethylene mulch with 125% of the recommended NPK.

Key Words : Potato, Polyethylene mulch, Planting methods, Fertility levels, Tuber yield

INTRODUCTION

Potato (*Solanum tuberosum* L.), popularly known as "The king of vegetables" is a native of South America and occupies the largest area under any single vegetable crop in the world. Potato is grown in India in almost all the states and under very diverse climate conditions. In an Area of 1.94 m ha with 41 m.t. production (Anonymous. 2013a). Out of total acreages under potato in India, hills occupy a substantial proportion, where the crop is grown throughout the year in one or the other part. In Himachal Pradesh, 152.98 thousand tonnes of potato produced from an area of 11.84 thousand hectares with an average productivity of 129 q ha^{-1} (Anonymous, 2013b). The state has also acquired the unique status as the primary seed producer in the country. In low and mid hills of Himachal Pradesh, potato is grown during autumn (September to December) and spring season (January to May).The spring crop is planted in the month of January when temperature is very low. This low temperature delays emergence and results in poor growth of the crop in the initial months and thereby contributes to low productivity.

The role of mulching in creating the environment favourable for the crop growth and thereby increasing the crop production is well established. Practice of mulching in potato crop maintains the optimum temperature and moisture content in the soil. It helps in maintaining a higher carbon dioxide regime around the plants. Plastic film mulching also ensures better fertilizer use through activation of beneficial microbes and prevent leaching losses. The colour of mulch determines its energy radiating behavior and influence on the microclimate around the plant. The surface temperature of the mulch and underlying soil temperature are also influenced by colour of the film. Most commonly used plastic mulches are black and clear plastic mulch, while red, blue, orange – green or yellow mulches are also in use these days in vegetable crop production (Lament, 1993). Nutrient management is an important factor responsible for increasing yield and quality of potato tubers (Raskar, 2003). Balanced and adequate fertilization plays a major role in determining these parameters and therefore, profitability of potato cultivation as potato is known to be a nutrient exhaustive crop and requires higher input of nutrients for realizing optimum yield. Similarly, method of planting has also a pronounced effect on the growth, development, productivity and quality of potato. Therefore, the effect of these factors need to be explored in the present context.

MATERIAL AND METHODS

The experimental site was located at 32° 6' N latitude, 76° 3' E longitude at an altitude of 1290 m amsl. The site falls in the sub-temperate mid hill zone of Himachal Pradesh. The field experiment was laid out in split plot design consisting of three replications.The treatments consisting of three mulching V_1-Black *polyethylene,* V_2-Transparent *polyethylene* mulch, V_3– No mulch with two planting methods M_1– Ridge method, M_2–flat bed method in main plots and three fertility levels in sub plots which were: F_1– 75% of recommended NPK, F_2 –100% of recommended NPK (120-80-60 kg N, P_2O_5 and K_2O/ha and F_3–125% of recommended NPK. All other recommended package of practices and plant protection measures were followed to raise the crop.

During the study period (January 2012 to May, 2012), mean maximum temperature ranged from 13.9°C in February to 32.7°C in May. The mean minimum temperature during these corresponding months remained 3.3°C and 18.8°C, respectively. A total rainfall of 205 mm was received. Relative humidity ranged from 29.3 to 72.9% during the entire cropping season. Soil of the experimental site was acidic in reaction, silty-clay loam in texture, low in available nitrogen, medium in available phosphorus and potassium.

Potato tubers (var. Kufri Jyoti) were either sown as whole tuber or bigger sized tubers were cut into pieces of about 50 g each and treated with carbendazim @ 2.5 g/l of water for 30 min. and planted on January 27, 2012. Planting was done at a spacing of 60 cm row to row and 20 cm plant to plant in flat beds or ridges made manually as per the treatments.

After planting of potato in flat beds or ridges as per treatments, plastic mulch of 20 micron thickness, black or transparent polyethylene (as per treatments) in colour was spread on soil plot wise, covering tightly with sufficient soil from all the sides. A three inch slit was cut along each row zone to facilitate the germination of tubers. The polyethylene sheet was folded to one end at the time of irrigation and fertilizers application and was again spread tightly. The polyethylene sheet was removed 90 DAP.

RESULTS AND DISCUSSION

Plant height

Plant height of potato plants recorded at harvest with black polyethylene mulch and transparent polyethylene mulch treatment was at par and significantly higher than no mulch (Table 1). This could be attributed to faster emergence facilitated by higher temperature and moisture content of the soil due to plastic mulching. These findings are in conformity with those of Zhao *et al*. 2012. Ridge method of planting resulted in significantly taller plants as compared to flat bed method (Table 1). It might be due to better soil conditions with respect to soil air, moisture and nutrient availability under ridge method. These results confirmed the findings of Qasim *et al.* (2013). The gradual increase in fertility levels from 75 to 100% and further to 125% NPK resulted in consistent increase in plant height. Such a response with respect to plant height in soil having low to medium fertility status was quite obvious. Similar results were also reported by Singh and Ahmed (2008).

Dry matter accumulation

Black polyethylene mulch resulted in significantly higher dry matter accumulation which was at par with transparent mulch compared to no mulch at harvest (Table 1). With the increased plant height in mulched plots, above ground dry matter also increased. This may be due to the reason that mulching prolonged the duration from seedling to maturity and increased plant height, LAI and thus more dry matter accumulation was recorded in mulched plots. These results are in accordance with those of Zhao *et al*. (2012). Among the planting method treatments, ridge method resulted in significantly higher dry matter accumulation compared to flat bed method (Table 1). It could be ascribed to better growth in terms of plant height and LAI due to better growing conditions under this method of planting.

Table 1. Effect of different treatments on growth parameters, yield attributes, productivity and graded yield of potato

Treatments	At harvest				Tubers number/ plant	Tubers weight/ plant (g)	Weight of tuber (g)	Tuber yield (q/ha)	Haulm yield (q/ha)	Grade A (>75 g)	Grade B (50-75 g) (q/ha)	Grade C (<50 g)
	Plant height (cm)	Dry matter accumulation (g)	Leaf area index	Number of haulms/ plant								
Mulching												
Black poly mulch	45.3	234.2	3.77	4.46	8.2	382.3	47.4	316.6	23.42	127.7	120.4	68.5
Transparent poly mulch	44.6	227.6	3.19	4.31	8.1	366.6	45.4	301.1	22.76	120.8	116.1	64.2
No mulch	36.8	190.6	2.88	3.97	6.3	257.9	41.6	212.9	19.06	71.2	81.4	60.2
CD (P=0.05)	2.5	13.2	0.13	0.31	0.6	12.3	3.1	5.9	1.32	8.4	3.8	3.3
Planting method												
Ridge method	44.0	223.5	3.49	4.28	7.8	352.9	45.1	289.2	22.35	115.9	110.5	62.7
Flat bed method	40.4	211.4	3.07	4.22	7.2	318.3	44.5	264.5	21.14	97.3	101.3	65.9
CD (P=0.05)	2.1	10.7	0.11	NS	0.5	10.0	NS	4.8	1.07	6.9	3.1	2.7
Fertility level												
75% NPK	39.9	202.8	2.76	3.99	7.0	306.8	42.3	252.3	20.28	78.0	94.2	80.1
100% NPK	42.2	219.4	3.20	4.26	7.5	341.7	46.3	279.4	21.94	115.8	105.0	58.6
125% NPK	44.7	230.3	3.89	4.48	8.0	358.3	45.8	298.9	23.03	125.9	118.6	54.4
CD (P=0.05)	2.1	10.8	0.19	0.36	0.4	9.7	2.7	8.9	1.08	3.4	4.5	4.5

Among different fertility levels, application of 125% of the recommended NPK recorded significantly highest dry matter accumulation followed by 100% of the recommended NPK and 75% of the recommended NPK recorded lowest dry matter accumulation (Table 1). This may be due to the reason that the crop growth rate increased with increasing nutrient level and resulted in higher dry weight. These results are in accordance with those of Jimenez *et al.* (2011) and Sarkar *et al.* (2007).

Leaf area index

Leaf area index was significantly highest with the application of black polyethylene mulch followed by transparent polyethylene mulch and lowest in un-mulch plots. Higher growth rate in terms of increased plant height and above ground dry matter due to plastic mulching might have increased leaf area index of potato. Similar results were reported by Jimenez *et al.* (2011). Data presented in Table 1 also indicated that planting of potato on ridges recorded significantly higher leaf area index than flat bed method. In case of fertility levels, 125% of the recommended NPK recorded significantly highest leaf area index followed by 100% of the recommended NPK and lowest with 75% NPK (Table 1). These results are in accordance with those of Kumar *et al.* (2010).

Number of haulms per plant

Number of haulms per plant produced with application of black polythene mulch was at par with transparent polythene mulch and significantly higher than no mulch (Table 1). Higher number of haulms per plant in plastic mulched plots could be attributed to the better hydrothermal regimes of soil which might have resulted into better crop growth. These results are in accordance with those of Jalil *et al.* (2004). Planting methods, however, showed no significant effect on number of haulms per plant. Gradual increase in fertility levels from 75 to 125% NPK increased number of haulm per plant significantly. However, the difference between 75% and 100% NPK and 100% and 125% NPK was not significant. These results were in accordance with those of Nizamuddin *et al*. (2003).

Number of tubers per plant

Data presented in Table 1 revealed that average number of tubers produced per plant under black polyethylene mulch treatment was at par with transparent polyethylene mulch and statistically superior to no mulch. These results are in accordance with those of Jalil *et al.* (2004). In case of planting methods, planting of tubers by ridge method significantly increased average number of tubers per plant compared to flat bed method. These results are in accordance with those of Singh *et al.* (1983). Among Fertility levels, application of 125% of the recommended NPK recorded significantly highest average number of tubers per plant followed by 100% of the recommended NPK and lowest number of tubers per plant was found in 75% of the recommended NPK. These results are in accordance with those of Nizamuddin *et al.* (2003).

Weight of tubers per plant

Mulching, planting methods and fertility levels showed significant effect on average weight of tubers per plant (Table 1). Significantly maximum weight of tubers per plant was obtained with black polyethylene mulch treatment followed by transparent polyethylene mulch and lowest average weight of tuber per plant recorded in un mulched plots. These results were in conformity with the findings of Uniyal and Mishra (2003). Ridge method of planting also resulted in significant improvement of average weight of tubers per plant over flat bed method of planting due to better crop growth under favourable soil conditions with ridge method of planting. Similar results reported by Singh *et al.* (1983). Gradual increase in fertility levels from 75% to 125% of the recommended NPK resulted in increase of average weight of tubers per plant consistently and highest weight was recorded at 125% NPK followed by 100% and lowest at 75% NPK. This consistent increase with increase in fertility level over the preceding level could be attributed to the enhanced growth of plant due to improvement in nutrition of the crop.

Average weight of tuber

Application of black polyethylene mulch recorded significantly higher average weight of tuber compared to no mulch and the former was statistically at par with transparent polyethylene mulch (Table 1). Application of 100% of the recommended NPK remaining at par with 125% of the recommended NPK significantly improved the average weight of tuber over 75% NPK.

Tuber yield

Application of black polyethylene mulch resulted in significantly highest tuber yield (316.6 q ha^{-1}) followed by transparent polyethylene mulch (301.1 q ha^{-1}) and lowest tuber yield was recorded from un-mulched plots (Table 1). On an average, black polyethylene mulch and transparent polyethylene mulch recorded 48.7 and 41.4% higher tuber yield over no mulch, respectively. This increase in tuber yield is attributed to the favourable environment provided by plastic mulch for condusive growth and development of potato crop. Higher yield advantage under black plastic film compared to transparent film may be explained in terms of relatively higher soil temperature and weed suppression achieved. These results were in accordance with those Singh and Ahmed (2008) and Thakur *et al.* (2000). Planting potato in ridge method also resulted in significantly higher tuber yield compared to flat bed method. The yield increase to the tune of 9.3% was observed under ridge method over flat bed method of planting. It might be due to better soil conditions with respect to soil air, moisture and nutrient availability under ridge method.

Gradual increase in fertility levels from 75% NPK to 125 % NPK increased potato tuber yield significantly and consistently. Significantly highest tuber yield (298.9 q ha^{-1}) was obtained with the application of 125% NPK followed by 100% NPK (279.4 q ha^{-1}). Application of 100% NPK increased the tuber yield to the tune of 10.8% whereas further increase in fertility level to 125% increased the yield by 18.5% over 75% NPK level. These results could very well be attributed to better growth and development of potato plants and significant improvement in all the yield contributing characters of crop due to improved plant nutrition with increasing fertility levels. These results are in conformity with the findings of Shah and Ismail (1983) and Datt *et al.* (2002).

Haulm yield

Haulm yield with black polyethylene mulch treatment was at par with transparent mulch and resulted in significantly higher haulm yield compared to un-mulched plots (Table 1). Ridge method of planting resulted in significantly higher haulm yield compared to flat bed method. Similarly, 125% NPK was statistically superior to 100% NPK and latter treatment was significantly better than 75% NPK. The effect of mulching, planting method and fertility levels on haulm yield followed the similar trend to that of tuber yield and hence is understandable. These results are accordance with those of Pawar *et al.* (2002).

Grading of potato tubers

Data presented in Table 1 indicated that potato crop mulched with black or transparent plastic film gave highest yield of A grade tubers followed by B grade and lowest yield of C grade tubers. However, under un-mulched crop highest yield of grade B tubers followed by grade A and grade C tubers was obtained. Similarly, ridge planting also resulted in more yield of grade A tubers followed by grade B and lowest yield of grade C tubers. However, under flat bed planting method highest yield was of grade B tubers followed by grade A tubers. Among different fertility levels, 100% NPK and 125% NPK resulted in highest yield of grade A followed by grade B and grade C tubers. Whereas at 75% NPK highest yield of grade B followed grade C and grade A tubers was obtained.

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Effect of nitrogen management on yield attributes and yield of rice

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ABSTRACT

Field experiment was conducted at Anbil Dharmalingam Agricultural College and Research Institute, Tiruchirapalli, Tamil Nadu during 2006 to 2007, with a view to study the nitrogen management for rice under SRI technique in alkali soil. The field experiment was laid out in Randomized Block Design with three replications using TRY1 as the test variety. There were ten treatments consisted of application of 100% RDF and their combination along with biofertilizer, 125% RDF+biofertilizer, LCC based nitrogen application (cv - 3, 4 and 5), 50% N through organic sources and 50%N through inorganic sources, 100% N through organic sources, without N application P and K, RDF and absolute control. It revealed that the different sources and levels of nitrogen had positive influence on the yield attributes and yield of rice. The yield attributes *viz.*, productive tillers, number of grains per panicle, number of filled grains per panicle and thousand grain weights were favourably increased by the application of 100% N through organic sources. The grain yield was also significantly enhanced by 125% RDF+biofertilizer. The straw yields also followed the same trend.

Key words : Rice, nitrogen nutrition, yield, nutrient uptake, SRI

INTRODUCTION

Rice is the world's most important crop and has supported a greater number of people for a longer period of time than any other crop. The great challenge of today is to ensure that rice production keeps pace with the burgeoning population. In India, enhanced rice production is needed not only for food security but also for the livelihood of millions of small and marginal farmers and landless labourers' families. Rice has the largest yield potential which is to be tapped with a sound management technology. Most of the rice growers rely on chemical fertilizers, especially nitrogenous fertilizers, to maximize the grain yield. However, abundant and imbalance use of chemical fertilizer not only reduced the soil fertility, and induced acidification but also polluted the environment. The use efficiency of applied fertilizer nitrogen by rice crop is very low; Nitrogen Use efficiency ranges from 30 to 40% (Prasad and De Data, 1979). Hence, the present study was conducted to evaluate rice for varying sources and levels of nitrogen management under SRI technique.

MATERIALS AND METHODS

Field experiment was conducted during *Rabi*, 2006 at Anbil Dharmalingam Agricultural College and Research Institute, Tiruchirappalli to evaluate the yield, nutrient uptake and fertility status of the soil. The soil of the experimental field was sandy loam texture with 8.92 pH, 0.56% OC, 0.53 dS m-1 EC and 246, 15.6 and 284.12 kg ha^{-1} available N, P and K, respectively. Altogether ten treatments replicated thrice in a randomized block design as follows :-
Treatment details

- T_1 100% recommended dose of fertilizer (RDF) @ 120 : 40 : 40 kg of N, P, K ha^{-1}
- T_2 100% RDF+biofertilizer (2 kg *azospirillum* ha^{-1})
- T_3 125% RDF+biofertilizer (2 kg *azospirillum* ha^{-1})
- T_4 LCC based N application (cv-3)
- T_5 LCC based N application (cv-4)
- T_6 LCC based N application (cv-5)
- T_7 50% N through organic and 50% N through inorganic sources

T_8 100% N through organic sources
T_9 No nitrogen (P & K RDF)
T_{10} Absolute control ($N_0P_0K_0$)

Fifteen days old seedlings of **Trichy -1** (TRY-1) variety were transplanted on 09.09.2006 at a spacing of 25 x 25 cm keeping single seedling per hill. At the time of last puddling, 25, 100 and 50% of recommended N, P and K were broadcasted uniformly. Remaining N was top dressed in 3 equal splits at 21, 42 and 63 days after transplanting (DAT). Remaining potassium was top dressed at 42 days after transplanting (DAT).

The observations on yield attributes and yield were recorded at the time of harvest like number of productive tillers per hill, number of grains per panicle, number of filled grains per panicle, thousand grain weights. The crop was harvested in 27.01.2007. The crop duration was increased by 10 days in 100 % N through organically manured treatment. All the data's were analyzed by using AGRES software and presented in the table

RESULTS AND DISCUSSIONS

Productive tillers/hill

Application of nitrogen through organic sources as well as its level had positive response on the productive tillers (Table 1). Among the different treatments, application of nitrogen 100% through organic sources (T_8) recorded the highest number of productive tillers per hill (20.3) which was followed by 125% RDF +biofertilizer (T_3). Application of biofertilizer favourably influenced the productive tiller number compared to RDF alone. The lowest number of productive tillers was observed in control (T_{10}). Similar findings were also reported by Alagesan (1997) and Subhendu and Adhikary (2005) who proved the positive correlation between N application and formation of productive tillers. Use of higher dose of N might have helped in inducing good vegetative growth (Paikaray *et al.,* 2001; Sugandhi *et al.*, 2003, and Singh and Singh, 2005) and thus produced higher number of panicles leading to higher yield.

Number of grains per panicle

Number of grains per panicle registered a sharp increase with nitrogen application through different sources (Table 1) and this was followed by 125% RDF +biofertilizer application recorded 276.4 grains per panicle. Application of 100% N through organic sources registered the highest number of grains per panicle. Application of biofertilizer through seed treatment and soil application along with RDF significantly increase the grain number compared to RDF alone (T_1). The lowest number of grains per panicle was registered with control. Increase in number of grains under increased nitrogen levels might be due to N-induced enhancement in photosynthetic activity and thus resulted in the translocation of photosynthates and amino acids from the leaves and culms to the grain (Dhyani and Mishra, 1994). It is in accordance with findings of Belder *et al.* (2005).

Table 1. Effect of different sources and levels of nitrogen in yield components of rice under SRI technique

Treatments	Productive tillers $hill^{-1}$ (No.)	Grains $panicle^{-1}$ (No.)	Filled grains $panicle^{-1}$ (No.)	1000 grain weight (g)
T_1- 100% recommended dose of fertilizer (RDF)	15.5	270.3	211.2	23.65
T_2 - 100% RDF+Biofertilizer	18.3	271.5	219.4	23.82
T_3 - 125% RDF+Biofertilizer	19.2	276.4	224.3	24.04
T_4 - LCC based N application (cv-3)	13.6	219.0	158.6	23.16
T_5 - LCC based N application (cv-4)	14.5	252.3	180.3	23.32
T_6 - LCC based N application (cv-5)	14.8	257.6	201.5	23.57
T_7 - 50% N through organic and 50% N through inorganic sources	16.9	258.8	222.7	23.94
T_8 - 100% N through organic sources	20.3	286.5	240.8	24.21
T_9 - No nitrogen (P & K RDF)	11.4	199.4	120.4	23.03
T_{10} - Absolute control	8.3	179.2	100.4	22.84
SEd	0.1	1.2	1.5	0.02
CD (0.05)	0.2	2.5	3.1	0.03

Table 2. Effect of different sources and levels of nitrogen in grain and straw yield of rice under SRI technique

Treatments	Grain yield (kg/ha)	Straw yield (t/ha)
T_1- 100% recommended dose of fertilizer (RDF)	5648	11.97
T_2 - 100% RDF+Biofertilizer	5889	12.15
T_3 - 125% RDF+Biofertilizer	6127	12.5
T_4 - LCC based N application (cv-3)	4218	8.5
T_5 - LCC based N application (cv-4)	5055	10.33
T_6 - LCC based N application (cv-5)	5583	10.61
T_7 - 50% N through organic and 50% N through inorganic sources	5938	12.13
T_8 - 100% N through organic sources	6710	13.1
T_9 - No nitrogen (P & K RDF)	3217	5.27
T_{10} - Absolute control	2316	4.52
SEd	41	0.1
CD (0.05)	87	0.2

Number of filled grains per panicle

Number of filled grains per panicle also registered a sharp increase with nitrogen application through different sources (Table 1) and this was followed by 125% RDF + biofertilizer which were recorded 224.3 filled grains per panicle. Application of 100% N through organic sources registered the highest number of filled grains per panicle. Application of biofertilizer through seed treatment and soil application along with RDF significantly increase the grain number compared to RDF alone (T_1). The lowest number of filled grains per panicle was registered with control. Sugandhi *et al.*, 2003 also reported the similar findings.

Test weight

Test of grain weight of grain was favourably influenced by application of nitrogen through different sources and its level. Application of 100% N through organic sources recorded maximum test weight of 24.21 g. This was followed by application of nitrogen through 125% RDF with biofertilizer. The test weight of grain was lowest in control treatment. It is similar to the results indicated by Shivay and Singh (2003) and Singh and Singh (2005). Continuous supply of N due to slow and steady release of mineralized N into soil solution to match the required absorption pattern of rice plant which enables to maintain the optimum N content of the rice plant needed for various yield determining factors like number of grains per panicle, filled grain percent and thousand grain weight.

Effect on grain and straw yield

Different nutrient management and straw package exerted positive influence on the grain yield of rice (Table 2). Application of 100% N through organic sources *viz*., daincha and vermicompost produced the highest grain yield of 6710 kg ha^{-1} which was 9.1% higher than the next best treatment of 125 % RDF + biofertilizers applied plot. The same trend was noticed in straw yield sources positively resulted in higher straw yield of 13.1 t ha^{-1}. The lowest amount of both grain and straw yield was registered with control. This was confirmed by Shekar *et al*. (2005) and Thilagavathi *et al.* (2005). The increase in straw yield was also due to the enhanced nutrient uptake throughout the crop growth period under increased nitrogen management. This is in accordance with findings of Thakur *et al.* (1995) and Parasuraman. (2005).

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Productivity and Profit Gain in Traditional Basmati Rice (Var. CSR 30) through Front Line Demonstrations

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ABSTRACT

The Study was carried out at farmers' field during the 2008-09 to 2012-13 in Panipat district of Haryana to explore the chance and possibility of yield gain in traditional basmati rice through the adoption of recommended technology package and also to analyze the price trends for formulating a coherent strategy for the promotion of traditional basmati rice. In the state of Haryana and other states falling within the Indo-Gangetic Plains (IGP) this crop is largely grown sequentially with wheat in an annual rotation, thus constituting a rice-wheat cropping system. This study established that the recommended technology package for traditional basmati rice is not only more productive but is also more profitable than the farmer's practice. The average yield gain in the demonstration over the local check was 7.7% and the same may be called as substantial and appreciable in the crop such as rice where the yield plateau is apparent and technological breakthroughs involving significant yield gains are not happening for the last many years. The net additional returns in demonstration over the local check ranged from Rs. 2372 to Rs. 7223/ha with an average of Rs. 5481/ha. The benefit-cost ratio was more favourable in the demonstration than the local check during all the years of study. It was further revealed that traditional basmati area can be promoted and sustained in the existing rice-wheat cropping system by ensuring the price edge and that the price of traditional basmati rice should be 2.5 times to that of coarse rice and 1.5 times to the evolved basmati rice for the simple reason that the yield of traditional basmati rice is proportionately low. The above said price edge is justified in the context of resource conservation and export stake in the international market. This study established the relevance and importance of the Front Line Demonstration even where the scope of yield gain are too limited and same may be conducted to reduce the cost of production and also to address the ecological considerations.

Key words : Front Line Demonstration, local check, traditional basmati rice, extension gap, productivity, economic returns, price trends

INTRODUCTION

Rice is the principal food crop of the country and is grown in different agro- ecological matrix. In the state of Haryana and other states falling within the Indo-Gangetic Plains (IGP), this crop is largely grown sequentially with wheat in an annual rotation, thus constituting a rice-wheat cropping system. In the state of Haryana, this crop occupies around 1.2 m ha area. Rice crop grown in the state of Haryana is divisible in three broad categories namely traditional basmati rice, evolved basmati rice and high yielding/coarse grain rice. Among the three broad categories, the cultivation of traditional Basmati rice is highly desirable because it requires less quality fertilizers, water, grows well even on marginal soils, and thereby considered as resource conserving technology within the domain of rice-wheat cropping system (Lathwal *et al.,* 2008). There is added advantage that the country gets precious foreign exchange through its export. In the recent years, reverse trend is observed wherein the area shift from the traditional basmati rice to evolved basmati rice and coarse rice has occurred. The comparative low yield levels coupled with the loss of price edge are responsible for this negative development. Under these circumstances or under such, it was considered worthwhile to conduct the Front Line Demonstrations (FLD) at farmer's field to explore the chance and possibility of yield gain in traditional basmati rice through the adoption of recommended technology package and also to analyze the price trends for formulating a coherent strategy for the promotion of traditional basmati rice in the pursuit of sustaining the rice-wheat cropping system. In the light of above facts, this investigation was carried out.

MATERIALS AND METHODS

This Study was carried out at farmers' field during 2008-09 to 2012-13 in Panipat district of Haryana to evaluate the recommended technology package in Traditional basmati rice (Variety CSR 30). This district is situated in the high potential Rice-Wheat belt of the state. Rice occupies about 75 % of total cropped area in *kharif* season and all of it is puddle transplanted rice. At 10 selected sites, traditional basmati rice (Variety CSR 30) was grown in a field of 0.4 ha using recommended technology. The soils of the experimental fields were loamy in texture having pH range from 7.9 to 8.4, low in nitrogen, low in available phosphorus and high in available potash. Each plot was separately harvested and yield data was recorded. Economic analysis was done in terms of market price, variable cost involved, gross returns, net returns and benefit-cost ratio. The production package being followed by the farmers in neighbouring fields was also monitored along with the recording of the data on various parameters so as to serve as a local check. The data so recorded from the demonstration plot and local check were compared to assess the performance of recommended technology in comparison to local check and attempts were also made to analyze the correlated factors to define most feasible approach to promote traditional basmati rice in overall agro-ecological matrix along with the necessary policy initiatives.

RESULTS AND DISCUSSION

Extension gap

The extension gap represents the possible productivity gain by the use of recommended technology. Such gap was as high as 12.03% in the year 2008-09 but reduced to a meager 5.8% in 2012-13. The average extension gap was 7.7% (Table-1). It was observed during the course of the study that farmers are able to tackle the routine problems of crop production and protection. To the contrary, farmers lack in technological and knowledge terms wherever any new yield limiting factor sets in and the delayed and inadequate response translates in major yield penalty. The same phenomenon operated in the year 2008-09 when the crop was badly infested with brown plant hoppers and the farmers were not acquainted with its control measures. To the contrary, this issue was reasonably addressed in demonstration plots and yield penalty was significantly reduced. Consequently, wide gap in the yield were obtained in local check and demonstration plot resulting into very high extension gap. The yield gain of 7.7 % is substantial and appreciable in the crop of rice where the yield plateau is apparent and technological breakthroughs involving significant yield gain are not happening for the last many years.

This study thus established the importance, relevance and essentiality of conducting the Front Line demonstrations at farmers field where the dissemination and diffusion of technology is direct and speedy. The reducing extension gap in the subsequent years of the study also corroborates the efficacy of the Front Line Demonstrations in the transfer of technology and it is a worthwhile investment in the whole gamut of extension strategy. The data generated in real field situation may prove crucial input in planning process so that the public investment is directed and oriented with tangible gains in national income.

Grain Yield

The grain yield recorded in the demonstration was comparatively higher than the local check in all the years of study though the yield gap varied among the different years of study (Table-1). This trend corroborates the fact that recommended technology package is more productive than the one being followed by the farmers. The yield gap alone reveals the half story and low yield gap never means that the package followed by the farmers is equally good. The productivity output needs to be analyzed in the context of component technologies being followed. It was revealed that the package being followed by the farmers has many negative elements when compared with the recommended technology package. The farmers invariably have sub optimal plant population and tend to use excessive nitrogenous fertilizers. The pesticide load in the farmer's practies is substantially higher than the recommended package and pesticide use is most often divorced from contemporary problem of the insect pest and disease complex. This study established the superiority of the recommended technology package over the one being followed by the farmers not only in productivity terms but also within the paradigm of good agricultural practices.

There is considerable difference in the yield obtained in different years of study. The highest grain yield in both demonstrations and local checks was observed in 2009-10 whereas the lowest yield was obtained in 2008-09. The temporal yield variations may be attributed to typical weather condition in particular year and incidence of biotic stresses in the form of insect pest and disease complex. The incidence of plant hoppers, sheath blight and blast have emerged as major yield limiting factors in the recent years which translates in yield penalty of different magnitude in different years.

Market Price

The market price is the grey area in the cultivation of traditional basmati rice. The coarse rice is procured by the Government agencies at the support prices whereas the price of traditional basmati rice is determined by the market forces which at material times cause prejudice to the farmers. The volatility in the price lacks logic and rationale and the marketing is wholly defective. The highest selling price of Rs. 3465/q was observed in the year 2009-10 whereas lowest price of Rs. 1800/q was received by the farmers in the year 2011-12 (Table-1). The market price in each subsequent year should show increasing trend because of the increase in the cost of production and general inflation whereas this study reveals a negative trend. This issue has to be addressed by the government through suitable policy imperatives.

The market price in absolute terms may appear remunerative but when the mandate and target is to promote one particular enterprise against the other, it is the relative price that holds the key and becomes a relevant factor. Here the objective is to promote and sustain the traditional basmati rice along with and in place of evolved basmati rice and coarse rice, reasonable price edge ensuring the parity in net returns becomes the essential element. It was roughly calculated that the price of traditional basmati rice should be 2.5 times to that of coarse rice and 1.5 times to the evolved basmati rice for the simple reason that the yield of traditional basmati rice is proportionately low. Keeping in view the high stake in the context of resource conservation, export potential and glut condition in rice crop such a price edge is highly desirable. In the absence of such level playing field, the area under traditional basmati rice has diminished from 40% of the total rice area to meager 6-7% in District Panipat during the period of study. These findings corroborate the results of (Garg *et al.* 2006)

Cost of production

The data on cost of production reveals that cost incurred in the recommended package is higher than that of local check but the difference is not of such nature as to deter the farmers from adopting the recommended technology. Furthermore, the cost escalation in demonstration has not come through monetary inputs but largely through cultural practices such as ensuring the use of quality seed, optimum plant population, gap filling etc. It is worth mentioning that negative trend was

Table 1. Performance of Recommended Technology Package in Rice Crop (Var. CSR 30) under Front Line Demonstrations

Year	Treatments	Av. Yield (q/ha)	Increase over check (%)	Market price (Rs./ha)	Cost Rs./ha	Gross returns (Rs./ha)	Net returns (Rs./ha)	Net Additional returns (Rs./ha)	Benefit-cost ratio
2008-09	Local Check	21.6	-	2805	26218	60588	34370	-	2.31
	Demo.	24.2	12.03		26288	67881	41593	7223	2.58
2009-10	Local Check	35.8	-	3465	26500	124047	97547	-	4.68
	Demo.	38.1	6.43		26778	132017	105239	7692	4.93
2010-11	Local Check	27.5	-	2650	28540	72875	44335	-	2.55
	Demo.	29.3	6.6		28610	77645	48035	3700	2.71
2011-12	Local Check	28.6	-	1800	31670	51480	19810	-	1.63
	Demo.	31.3	9.4		34158	56340	22182	2372	1.65
2012-13	Local Check	31.3	-	2840	36905	88892	51987	-	2.41
	Demo.	33.1	5.8		35600	94004	58404	6417	2.64
Mean	Local Check	28.96	-	2712	29967	79576-	49610	-	2.66
	Demo.	31.20	7.7		31288	93332	55091	5481	2.98

observed in the year 2012-13 where the cost of production in the local check was comparatively more than that the one incurred in demonstration (Table 1). This information corroborates the fact that there is no monetary constraint in the adoption of the recommended technology and it is only the managerial issue which needs to be addressed. This clearly establishes that recommended technology package is not only more productive but may prove less costly. Such information do suggest that Front Line Demonstration may be conducted to reduce the cost of production and also to address the ecological considerations where the scope of yield gain are too limited as has been the case with rice and wheat in the agro-ecological niche of district Panipat.

Economic returns

The gross returns being the product of grain yield and market price were higher in demonstration than the local check in all the years of study. The trend is the same as obtained with respect to the grain yield. The net returns also followed the trend of gross returns because there was no big difference in the cost of production. The net additional returns in demonstration over the local check ranged from Rs. 2372 to Rs. 7223/ha with an average of Rs. 5481/ha (Table-1). The net additional return of significant amount establishes the economic superiority of the recommended technology package over the local check. The benefit-cost ratio was more favourable in the demonstration than the local check in all the years of study.

Conclusions

Despite the ecological damage, farmers are still persisting with rice crop in *kharif* season because there is no alternative crop which is equally remunerative. In order to sustain the rice crop, expansion of area under traditional basmati rice is critically required. This study established beyond doubt that recommended technology package is not only more productive but is also more profitable and furthermore it has the element of sustainability. Good impact of this study was observed in terms of the adoption of recommended technology though the area shift from traditional basmati rice to evolved basmati rice occurred due to unfavourable price terms. The scope lies for the reversal of this trend through suitable policy interventions and price policy. There is need to ensure remunerative price of traditional basmati rice in relative terms with suggested edge over the coarse rice and evolved basmati rice to accelerate the cultivation of Traditional Basmati Rice for resource conservation and diversification within the rice-wheat cropping system.

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Response of maize hybrid to nutrient management practices

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ABSTRACT

A field experiment was conducted during *kharif* seasons of 2013 and 2014 at Crop Research Station, Bahraich, N.D. University of Agriculture & Technology (U.P.) to study the response of maize hybrids to nutrient management practices. The treatment consisted of maize hybrids *viz.* PMH-1, PMH-3, CMH 08-292, CMH 08-350, CMH 08-287 and three levels of nutrients *viz* recommended (150:60:60 kg NPK/ha) Site Specific Nutrient Management (SSNM) (148:55:50 kg NPK/ha) and farmer practice (120:30:30 kg NPK/ha) were replicated thrice in spilt plot design. The maize hybrids were located in main plot and nutrient levels in subplots. The data of growth, yield attributes, yield, economics and nutrients uptake were recorded at different stages of crop growth and after harvesting of the crop. The economics of the treatments were calculated on nearest market price of input and produce. The experimental data revealed that the highest plant population/plot, number of cobs/plot, cob yield, girth of cobs, number of grain row/cobs, number of grain/row length of cobs, test weight, selling percentage, grain yield, stover yield and harvest index were recorded under maize hybrid PMH-3 and application of recommended dose (150:60:60 kg NPK/ha) of fertilizer, respectively. The highest grain yield 66.59 and 64.83 q/ha was recorded under the same treatment. The highest nutrient uptake 149.82:33.29:99.88 and 145.86:32.41:97.24 kg NPK/ha was also noted under maize hybrid PMH-3 and recommended dose of nutrients, respectively. The highest economics was also found under the same treatments.

Key words : Hybrids, nutrients, yield, economics, nutrient uptake

INTRODUCTION

Maize is an important cereal crop of India. It is cultivated over an area of 8.49 m ha with a production and productivity of 21.49 mt and 2.51 ton/ha, respectively. In U.P. It's covers an area of 1.8 m ha with production of 4.8 m t and average productivity of 1.4 t/ha. The need of both human and animal by providing food and fuel of them. It is a miracle crop because of its high yield potential and is also known as the queen of cereals. Introduction of hybrids having high yield potential with the assured supply of nutrient plays a vital role in enhancing the productivity of maize crop. Nitrogen, phosphorus and potash are indispensable elements for optimum growth and yield of crop. Keeping this view in mind a field experiment was laid out to evaluate the response of maize hybrids to nutrient management practices at Crop Research Station, Bhraich (U.P.).

MATERIALS AND METHODS

The field experiment was conducted at the Crop Research Station, Bahraich Uttar Pradesh during 2013 and 2014 in *kharif* season in the sandy loam soil. The rainfall of 950 mm and 980 mm were recorded during 2013 and 2014, respectively. More than 85 % rainfall was received during June to September in both of the years. The experimental soil was neutral in reaction (pH 7.5), low in the organic carbon (2.6 g/kg) and available N (260 kg/ha) and medium in available P (13.5 kg/ha) and available K (285 kg/ha). The treatment consisted of 5 major hybrids *viz.* PMH-1, PMH-3, CMH 08-292, CMH 08-350 and CMH 08-287 along with three levels of nutrient *viz.* recommended (150:60:60 kg NPK/ha)) Site Specific Nutrient Management (SSNM) (148:55:50 kg NPK/ha) and farmer practice (120:30:30 kg NPK/ha). The maize hybrids were located in main plot and levels of nutrients in sub plots and experiment was laid out in split plot design and treatment were replicated thrice. Crop was sown on 3rd July in both of the years of experimentation at a distance of 60 cm row to row and 20 cm plant to plant. The 1/3 dose of nitrogen and full dose of P and K was applied at the time of sowing as basal dressing through urea, single superphosphate and murate of potash. Rest 2/3 of nitrogen was applied as topdressing in two splits at knee high stage and silking stage of crop. The agronomical practices like weeding, intercultural operations and plant protection measures were adopted time to time as per requirement of the crop. The data of growth such as plant height, no. of plants/ plot and days to 50% flowering as well as yield attributing characters ware recorded. The crop was harvested after full maturity at 100 days duration. The economics of the treatments were calculated on the nearest market price of input and produce. The nutrient uptake by grain and stover were determined as per Jackson (1973). The statistical analysis was also done as par procedure advocated by Gomez *et al.* (1984).

RESULTS AND DISCUSSION

Effect of maize hybrids

The data (Table 1) indicated that the significantly highest plant height (204 cm) was recorded under maize hybrid CMH 08-292 which was 4.43, 9.87, 8.51 and 6.62 % higher over the hybrids PMH-1, PMH-3, CMH 08-350 and CMH 08-287, respectively. It might be due to higher elongation nature of variety, CMH 08-292. The data (Table 1) also indicated that significant differences were found among the tested five hybrids in days to 50 % flowering, no. of plants/plot, no. of cobs/ plot, length of cobs, no. of grain/row, no. of grain rows/ cob, cobs girth, test weight and selling percentage. The maximum days to 50 % flowering (60.33), no. of plants/ plot (39.33), no. of cobs/plot (40), length of cobs (20.8 cm), no. of grain/row (34.4), no. of grain rows/cob (18.4), cobs girth (10.8cm), test weight (246.33 g) and selling percentage (72) were recorded under hybrid PMH-3 over the hybrids PMH-1, CMH 08-292, CMH 08-350 and CMH 08-287 which might be due to genetical variation among the hybrids. Similar findings were also reported by Singh *et al.*, (2014), Farhan (2001) and Gozubenli *et al.*, (2001). The lowest plant height (185.66 cm) was noted under the hybrid PMH-3 which might be due to short strature nature of the same variety. The lowest value of growth and yield attributing characters were noted under the hybrid CMH 08-287 which might be due to poor genetic character of the same hybrid. The yield of grain and stover was recorded after harvesting of crop. The result (Table 1) revealed that the maximum grain and stover yield (66.59 and 90.12 q/ha, respectively) were recorded under the maize hybrid PMH-3 which might be due to higher yield attributing character recorded under same hybrid resulted into higher yield. The yield of grain under PMH-3 was 16.09, 24.58, 25.92 and 18.46 % higher over the variety PMH-1, CMH 08-292, CMH 08-350 and CMH 08- 287, respectively. The same trends were also noted in the stover yield of the hybrids. The maximum harvest index (41.49%) was recorded under the hybrid PMH-3 which was found 5.14, 12.04, 3.35 and 7.48 % higher over the hybrids PMH-1, CMH 08-292, CMH 08- 350 and CMH 08-287, respectively. The higher harvest index under the variety PMH-3 might be due to maximum grain yield recorded under same in respect of stover yield of hybrid.

The nutrient uptake by crop was determined in grain and stover of crop and reported in Table-2. Result revealed that the highest NPK uptake 149.82:33.29:99.8 kg/ha were noted under the hybrid PMH-3 which might be due to recorded higher grain and stover yield under the same hybrid. The lowest nutrient uptake 118.98:26.44:79.32 kg NPK/ha was recorded under maize hybrid CMH 08-350 which might be due to poor yield of grain and stover recorded under same hybrid. The nutrient uptake by different maize hybrid differ due to genetical character of variety.

The cost of cultivation of each treatment was worked out and data is presented in Table-2 which revealed that the higher net income of Rs. 73291 /ha was noted under the hybrid PMH-3 and lower net income of Rs. 52267/ha under the hybrid CMH 08-350. The significant variation in net returns among the maize hybrid may to due to variation in yield potential of hybrids. The net income under PMH-3 was 34.26, 40.43, 41.42 and 29.84% higher over the hybrid hybrids PMH-1, CMH 08-292, CMH 08- 350 and CMH 08-287, respectively. The maximum B:C of 3.11 was noted under the hybrid PMH-3 and minimum 2.50 in hybrid CMH 08-292. The variation in B:C might be due to different yield potential of hybrids.

Effect of nutrient management on growth, yield attributes and yield

The growth and yield attributes were recorded and presented in (Table 1). Data indicated that significant variation was recorded under different nutrient levels to the crop. The highest plant height (202.2 cm) was recorded under the nutrient levels 150:60:60 kg NPK/ha which was 0.7 and 15.0 % higher over the SSNM and farmer practice, respectively. The higher plant height under recommended

Table 1. Effect of nutrient management and hybrids on growth, yield attributes and yield of maize crop

Treatments	Plant height (cm)	Days to flowering 50%	No. of plant/ plot	No. of cobs/ plot	Cobs yield (kg/plot)	Length of cobs (cm)	No of grain/ row	No. of grain row/ cobs	Cob girth (cm)	Test weight (g)	Selling %	Grain yield (q/ha)	Stover yield (q/ha)	Harvest index %
Maize hybrids														
PMH-1	195.33	59.66	38.66	40.0	3.80	20.5	30.8	17.5	10.5	243.0	71.66	57.36	87.99	39.46
PMH-3	185.66	60.33	39.33	40.0	4.40	20.8	34.4	18.4	10.8	246.33	72.0	66.59	93.12	41.49
CMH 08-292	204.0	60.0	39.0	39.33	3.53	18.4	28.5	11.8	9.5	243.66	71.66	53.45	90.88	37.03
CMH 08-350	188.0	62.0	39.0	38.33	3.62	18.8	29.2	17.5	9.8	243.66	72.0	52.88	86.49	37.94
CMH 08-287	191.33	59.33	39.0	39.0	3.53	17.8	28.2	17.2	9.2	242.55	71.66	56.21	89.39	38.60
CD (P=0.05 %)	2.85	1.25	0.54	0.48	0.15	0.20	0.48	0.12	0.10	1.15	1.20	0.75	0.75	1.2
Nutrients levels														
Recommended Dose Fertilizer (RDF) (150:60:60) kg NPK/ha	202.2	62.0	39.2	40.0	4.32	20.75	31.5	19.2	11.2	245.79	72.8	64.83	91.04	41.61
Site Specific Nutrient Management (SSNM) (148:55:50 kg NPK/ha)	200.6	60.8	39.0	39.6	4.08	19.8	32.5	18.5	11.5	243.73	72.0	63.79	89.32	41.66
Farmer Practice (120:30:30 kg NPK/ha)	175.8	58.8	38.8	38.8	2.92	17.5	27.4	16.5	8.5	236.46	70.8	43.27	60.36	41.75
CD (P=0.05 %)	1.75	1.75	0.65	0.35	0.18	0.18	0.45	0.14	0.8	1.10	1.14	0.65	0.78	NS

dose (150:60:60 kg/h) might be due to higher levels of nutrients in comparison to the rest of the nutrient levels. The yield attributes such as no. of plants/plot, no. of cobs/plot, length of cobs(cm), no. of grain.row, no. of row/cobs, cobs girth (cm), test weight and selling percentage were significantly influenced by various levels of nutrients (Table 1). Fifty per cent flowering (62), no. of plants/plot (39.2), no. of cobs/plot (40), length of cobs (20.75 cm), no. of grain.row (31.5) no. of row/cobs (19.2), cobs girth (11.2 cm), test weight (245.79) and selling percentage (72.8 %) were noted under the levels of nutrients 150:60:60 kg NPK/ha (Recommended dose) over the SSNM (148:55:50 kg NPK/ha) and farmer practice (120:30:30 kg NPK/ha). The highest yield attributes under levels of nutrients 150:60:60 kg NPK/ha might be due to higher nutrients availability under the treatments for growth development and yield attributes the similar finding were also reported by Parthipan and Premsakehar (2003), Singh and Singh (2006), Singh and Sarkar (2001), Prassad *et al.*, (2005) Panwar *et al.*, (2006), Sahoo and Mahapatra (2007), Banarjee *et al.*, (2006) and Verma *et al.*, (2003). The lowest value of height and yield attributes were observed under the farmer practice (120:30:30 kg NPK/ha) which might be due to less availability of nutrient to crop. Under Site Specific Nutrient Management practice, the growth and yield attributes were higher in comparison to the farmer practice.

The grain and stover yield of crop were recorded after harvesting of crop and recorded data were reported in (Table-1) which indicated that the highest grain yield (64.83 q/ha) and stover yield (91.04 q/ha) were noted under the levels of nutrients 150:60:60 kg NPK/ha which was 1.72 and 49.82% higher in grain and 1.92 and 50.82% higher in stover over the levels of nutrients SSNM (148:55:50 kg NPK/ha) and farmer practice (120:30:30 kg NPK/ha), respectively. The higher grain and stover yield under the recommended dose of nutrients might be due to more availability of nutrients under the treatment ultimately yield of grain and stover increased. The similar results were also reported by Singh *et al.*, (2014), Singh *et al.*, (2013) and Ramchandrappa *et al.*, (2007).

Nutrient uptake by maize was applied significantly due to various treatments (Table-2). The NPK uptake by crop increased with application of recommended dose (150:60:60 kg NPK/ha). The higher uptake under this treatment might be due to more uptakes of nutrients. The lower uptake (97.35:21.63:64.90 kg NPK/ha) was determined under the farmer practice. It might be due to less availability of nutrients to the crop. The uptake of the nutrients were significantly influenced by different levels of nutrients. The results also supported by the finding of Singh *et al.*, (2014).

The economics of treatments were calculated

Table 2. Effect of nutrient management and maize hybrids on economics and nutrient uptake of maize crop

Treatments	Cost of cultivation (Rs./ha)	Total profit (Rs./ha)	Net profit (Rs./ha)	B : C	Total Nutrient uptake by grain and stover (kg/ha)		
					N	P	K
Maize hybrids							
PMH-1	35000.00	94440.00	59440.00	2.69	129.6	28.68	83.17
PMH-3	35000.00	108921.00	73921.00	3.11	149.82	33.29	99.88
CMH 08 -292	35000.00	87639.00	52639.00	2.50	120.26	26.72	80.17
CMH 08 -350	35000.00	87267.00	52267.00	2.49	118.98	26.44	79.32
CMH 08 -287	35000.00	56932.00	56932.00	2.62	126.47	28.10	84.31
CD (P=0.05 %)	NIL	1250.00	850.00	0.015	3.5	1.5	1.75
Nutrients levels							
Recommended Dose Fertilizer (RDF) (150:60:60) kg NPK/ha	35400.00	106554.00	71154.00	3.01	145.86	32.41	97.24
Site Specific Nutrient Management (SSNM) (148:55:50 kg NPK/ha)	35150.00	104481.00	69331.00	2.97	143.52	31.89	95.68
Farmer Practice (120:30:30 kg NPK/ha)	34600.00	71013.00	36413.00	2.05	97.35	21.63	64.90
CD (P=0.05 %)	NIL	1145.00	820.00	0.014	2.8	1.45	1.78

Price cost of grain – Rs. 1500/quintal.
Price of stover – Rs. 300/quintal.

Table 3. Interaction Effect of nutrient levels and hybrids on yield and net profit of hybrid maize

Treatments	Yield (q/ha) Cost of cultivation			Net profit		
	Recommended dose dose (150:60:60 kg NPK/ha)	SSNM (148:55:50 kg NPK/ha)	Farmer Practice (120:30:30 kg NPK/ha)	Recommended dose (150:60:60 kg NPK/ha)	SSNM (148:55:50 kg NPK/ha	Farmer Practice (120:30:30 kg NPK/ha
Maize hybrids						
PMH-1	61.09	60.57	50.31	65297.00	64385.00	47926.00
PMH-3	65.71	65.19	54.93	72537.00	71626.00	55167.00
CMH 08-292	59.14	58.62	48.36	61896.00	60985.00	44526.00
CMH 08-350	58.85	58.33	48.07	61710.00	60699.00	44340.00
CMH 08-287	60.52	60.0	49.74	64043.00	63131.00	46672.00
CD (P=0.05)	0.85			1525.00		

and presented in (Table-2) indicated that the higher net profit of Rs. 71154/ha and B:C 3.01 was received under the nutrients applied @ 150:60:60 kg NPK/h which was 2.62 and 95.40% higher in net profit and 1.34 and 46.82% higher in B:C over the nutrients levels SSNM and farmer practice, respectively. The lower net income of Rs. 36413 and B:C ratio 2.05 was noted under the farmer practice ultimately net income and B:C ratio was less.

Interaction effect of hybrids x nutrient levels

The data of yield and net profit presented in (Table 3) indicated that maximum grain yield 65.71 q/ha and net profit of Rs. 72537/ha was recorded under recommended dose of nutrients (150:60:60 kg NPK/ha) which was at par with hybrid PMH-3 X SSNM (148:55:50). The lower value of yield and net profit was recorded under every hybrid of maize in respect of farmer practice which might be due to lower levels of nutrients under farmer practice in comparison to recommended dose and SSNM levels of nutrients. The hybrid PMH-1 found at second place at all levels of nutrients (Table-3) in respect yield and net profit.

CONCLUSION

On the basis of two years experimentation, it may be concluded that the hybrid maize PMH-5 was found batter at all levels of nutrients application and hybrid PMH-1 found at second place. The hybrid PMH-3 may be recommended to the farmers grow at recommended dose of NPK 150:60:60 kg/ha to obtain maximum yield and with higher net profit.

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Expression of Bt cry toxins in cotton genotypes depend on developmental stage but not on age of leaves

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ABSTRACT

Extent of cry proteins in leaves is crucial to the protection expected against insects feeding on cotton leaves. The present study was carried out on eighteen cotton genotypes to quantify Bt toxin levels at two growth stages *viz*., vegetative and reproductive stage and in different plant parts (apical leaves, bottom leaves and squares). The results showed that quantitative levels of Bt toxin in cotton genotypes analysed were variable and in general were higher during vegetative stage (90 days after sowing) and decreased as the reproductive stage approached (120 DAS). However, the expression across the diverse plant parts remained comparable. Further, it was observed that Cry 1Ac levels were higher than that of Cry 2A throughout the vegetative and reproductive phases. Therefore, it was observed that cry toxin level decreases as the plant attains maturity. The genotypes showing high expression during late stage like MRC 6304, Bunty 2113-2, Platinum 605, MRC 7017 and RCH 134 may be more promising to fight out insect attack.

Key words : *Bacillus thuringiensis,* cotton, ELISA, expression, toxin, growth stage

INTRODUCTION

The development of insect resistant crop varieties has been the most successful application of agricultural biotechnology research so far. Insecticidal proteins from *Bacillus thuringiensis* (Bt) constitute the active ingredient in many biological insecticides and biotech crops expressing *B. thuringiensis* genes (Bt crops). For the control of lepidopteran pests, *B. thuringiensis* Cry1 and Cry2 class proteins are being used either in sprayable products or in transgenic plants (Ferre *et al,* 2008; Schnepf *et al*., 1998). Such transgenic Bt plants developed till date produce Cry toxins constitutively and confer continuous pest insect resistance without affecting non target insects or vertebrates (Betz *et al*., 2000; Romeis *et al*., 2006). Most extensively planted Bt crops express Cry1Ab (maize) or Cry1Ac (cotton), but second-generation products include the combination of Cry1Ac and Cry2Ab in cotton (Ferre *et al*, 2008). In all cases, *B. thuringiensis* proteins act by ingestion, and their mode of action is so specific that they are harmless to most non target organisms, beneficial insects, and vertebrates (Romeis *et al*., 2006). Bt cotton producing Cry1Ac toxin was commercialized to control *Heliothis virescens* (tobacco budworm) in the field, and this technology proved efficient in target control, chemical insecticide reduction, and environmental safety (Betz *et al*., 2000). One of the main issues related to use of this technology is the potential for development of resistance by target insect pests due to intense selection pressure (De Maagd, *et al*, 1999). Although altered toxin binding is the best-characterized mechanism of resistance, alteration of any step in the toxin mode of action can result in decreased susceptibility (Ferre and Rie., 2002). More than 50% of the global cotton area is now under genetically modified cotton (James, 2008, 2009). In India, area under *Bt* cotton has increased to 8.4 m ha in 2009 exceeding that of China's 3.4 m ha (James, 2009). The *Cry* protein in *Bt* cotton provides insecticidal activity against many Lepidopteran species. *Bt* toxins and their genes are a unique resource for agricultural system. Therefore, the main objective of the present study was to investigate the presence/absence of Cry toxin in Bt transformed cotton and to explore the class of Cry gene/toxin.

MATERIAL AND METHODS

The present study was carried out in the Department of Biochemistry, College of Basic Sciences and Humanities, Chaudhary Charan Singh Haryana Agricultural University, Hisar during the year 2012-13. Samples (apical and bottom leaves; and squares) of 18 cotton genotypes *viz.* RCH 134, MRC 6304, Ankur 3028, SP 7007, MRC 7017, JKCH 1050, Vibha 1544, Raja Kribco, Shakti 9, Platinum 605, Jadu, Vardaan, Pancham 541, Bioseeds 6588, Bioseeds 6488, Bunty 2113-2, Vich 310, Vich 309 were obtained from the fields of Cotton Section, Department of Genetics and Plant Breeding, CCS HAU, Hisar. Samples were stored at –80°C for analysis. Sandwich ELISA was used to quantify the Cry toxins (*Cry1A and Cry2A)* in the samples. Twenty milligram of each sample was weighed and ground manually using extraction buffer provided by the manufacturer. Preparation of samples, standards and ELISA were performed according to the manufacturer's instructions (Envirologix). Wells were examined visually as well as measured using ELISA plate reader at 450 nm and 630nm. Samples were taken from cotton plants at 90 DAS (days after sowing) and 120 DAS.

RESULTS AND DISCUSSION

Samples of 18 cotton genotypes *viz*. RCH 134, MRC 6304, Ankur 3028, SP 7007, MRC 7017, JKCH 1050, Vibha 1544, Raja Kribco, Shakti 9, Platinum 605, Jadu, Vardaan, Pancham 541, Bioseeds 6588, Bioseeds 6488, Bunty 2113-2, Vich 310, Vich 309 were analysed using sandwich ELISA for the quantification of two cry genes *viz. Cry1A* and *Cry2A.* From the results, it was observed that all the cotton genotypes showed positive reactions for both Bt genes. The toxin expression was also studied with respect to age and tissues. Apical leaves, bottom leaves and squares were collected from cotton plants at 90 DAS (days after sowing) and 120 DAS. Varying levels of cry toxins were observed using ELISA assay (Table1 and Table 2). It was observed that Cry 1A toxin level in apical leaf tissues ranged from 0.215 to 1.011 µg/g and in bottom leaf ranged from 0.398 to 1.043 µg/g at 90 DAS; at 120 DAS the toxin level in apical leaf tissues ranged from 0.198 to 0.917 µg/g and in bottom leaf ranged from 0.273 to 0.945 µg/g. It was observed that Cry 2A toxin level in apical leaf tissues ranged from 0.220 to 0.698 µg/g and in bottom leaf ranged from 0.284 to 0.773 µg/g at 90 DAS; at 120 DAS the toxin level in apical leaf tissues ranged from 0.208 to 0.557 µg/g and in bottom leaf ranged from 0.217 to 0.664 µg/g on fresh weight basis. MRC 6304 and Ankur 3028 expressed the highest amount of Cry1A and Cry2A toxin in apical leaf i.e., 1.011 µg/g, 0.987 µg/g and 0.698 µg/g, 0.662 µg/g respectively at 90 DAS; 0.917 µg/g, 0.821 µg/g and 0.557 µg/g, 0.550 µg/g respectively at 120 DAS. MRC 6304 and Ankur 3028 also expressed the highest amount of Cry1A and Cry2A toxin in bottom

Table 1. Quantification of Bt toxins in leaf tissues at 90 and 120 days after sowing (DAS)

Genotypes	Cry1A				Cry2A			
	Apical leaf		Bottom leaf		Apical leaf		Bottom leaf	
	90 DAS	120 DAS	90 DAS	120 DAS	90 DAS	120 DAS	90 DAS	120 DAS
RCH 134	0.847±0.012^{aA}	0.690±0.003^{aB}	0.964±0.002^{aC}	0.801±0.007^{aD}	0.220±0.002^{aA}	0.208±0.003^{aB}	0.284±0.002^{aC}	0.217±0.005^{aAC}
MRC 6304	1.011±0.004^{bA}	0.917±0.003^{bB}	1.043±0.003^{bC}	0.945±0.003^{bD}	0.662±0.003^{bA}	0.550±0.004^{bB}	0.753±0.003^{bC}	0.642±0.003^{bD}
Ankur 3028	0.987±0.002^{cA}	0.821±0.001^{cB}	0.994±0.003^{cC}	0.898±0.002^{cD}	0.624±0.003^{cA}	0.540±0.001^{cB}	0.690±0.001^{cC}	0.561±0.002^{cD}
SP 7007	0.802±0.001^{dA}	0.769±0.002^{dB}	0.863±0.001^{dC}	0.811±0.003^{dD}	0.486±0.006^{dA}	0.413±0.003^{dB}	0.652±0.001^{deC}	0.549±0.006^{dD}
MRC 7017	0.874±0.003^{e}	0.813±0.001^{e}	0.970±0.002^{a}	0.840±0.004^{e}	0.464±0.002^{e}	0.393±0.002^{e}	0.560±0.002^{f}	0.464±0.001^{e}
JKCH 1050	0.767±0.007^{f}	0.684±0.001^{f}	0.790±0.003^{e}	0.711±0.003^{f}	0.407±0.003^{f}	0.360±0.002^{f}	0.497±0.001^{h}	0.353±0.001^{f}
Vibha 1544	0.434±0.002^{g}	0.400±0.001^{g}	0.510±0.001^{f}	0.468±0.002^{g}	0.541±0.001^{g}	0.432±0.002^{g}	0.584±0.001^{fg}	0.442±0.002^{g}
Raja Kribco	0.584±0.001^{h}	0.471±0.001^{h}	0.630±0.004^{g}	0.539±0.003^{h}	0.448±0.006^{i}	0.374±0.003^{h}	0.656±0.032^{d}	0.539±0.002^{h}
Shakti 9	0.639±0.001^{i}	0.526±0.002^{i}	0.670±0.008^{h}	0.654±0.002^{i}	0.560±0.002^{h}	0.393±0.002^{i}	0.607±0.001^{d}	0.495±0.005^{i}
Platinum 605	0.850±0.004^{a}	0.732±0.002^{j}	0.909±0.004^{i}	0.869±0.002^{j}	0.550±0.001^{gh}	0.471±0.003^{k}	0.594±0.001^{g}	0.421±0.001^{j}
Jadu	0.345±0.003^{j}	0.287±0.002^{k}	0.441±0.001^{j}	0.358±0.001^{k}	0.439±0.002^{i}	0.319±0.003^{l}	0.581±0.001^{fg}	0.408±0.004^{k}
Vardaan	0.522±0.002^{k}	0.467±0.001^{h}	0.611±0.002^{k}	0.562±0.003^{l}	0.589±0.002^{j}	0.457±0.002^{m}	0.603±0.001^{d}	0.566±0.005^{l}
Pancham 541	0.664±0.002^{l}	0.545±0.002^{l}	0.754±0.003^{l}	0.681±0.001^{m}	0.636±0.003^{cA}	0.546±0.003^{bcA}	0.641±0.001^{dB}	0.564±0.002^{clC}
Bioseeds 6588	0.479±0.003^{m}	0.394±0.002^{m}	0.564±0.003^{m}	0.500±0.001^{n}	0.592±0.002^{j}	0.474±0.005^{k}	0.614±0.002^{d}	0.560±0.004^{cl}
Bioseeds 6488	0.516±0.003^{kA}	0.467±0.002^{hA}	0.586±0.006^{nA}	0.464±0.003^{oB}	0.550±0.002^{ghA}	0.470±0.001^{kB}	0.684±0.028^{cC}	0.655±0.003^{m}
Bunty 2113-2	0.777±0.003^{faA}	0.715±0.002^{nB}	0.843±0.003^{oC}	0.837±0.003^{eB}	0.656±0.003^{b}	0.543±0.002^{c}	0.629±0.001^{d}	0.582±0.002^{n}
Vich 310	0.360±0.002^{n}	0.290±0.001^{k}	0.450±0.004^{j}	0.377±0.002^{g}	0.698±0.017^{k}	0.560±0.001^{n}	0.773±0.002^{b}	0.664±0.003^{m}
Vich 309	0.215±0.003^{o}	0.198±0.005^{o}	0.398±0.002p	0.273±0.001^{p}	0.571±0.00^{l}	0.485±0.002^{o}	0.656±0.001^{e}	0.538±0.006^{h}

a,b,c …p: values with different superscripts within a column differ significantly ($p<0.05$).
A, B,C,D; values with different superscripts within a row differ significantly ($p<0.05$) (for each of Cry1a and Cry2a separately).

leaf i.e., 1.043 µg/g, 0.994 µg/g and 0.773 µg/g, 0.753 µg/g respectively at 90 DAS; 0.945 µg/g, 0.898 µg/g and 0.664 µg/g, 0.642 µg/g respectively at 120 DAS. It was also observed that irrespective of the age of the leaves the level of Bt Cry toxin depend on the developmental stage of the plant. It was observed that Cry1A and Cry2A toxin levels differed among all the cotton genotypes and were found to decrease as the plants attained maturity. The Cry 1Ac levels were found to be higher than that of Cry 2A throughout the growth phases and the cry toxin levels decreased as the plants attained maturity.

The toxin levels also differed in the apical and bottom leaves of the same plant and was found to be higher in the bottom leaves as compared to the apical leaves (Table 1). Greenplate *et al*. (2001) reported that the appropriate plant parts containing sufficient levels of Cry proteins play significant roles against harmful insect-pests. Kranthi *et al*. (2005) and Mahon *et al*. (2002) reported that the Bt toxins in different tissues of the cotton plant vary throughout its life cycle. Due to this, the tolerance of cotton plants towards target pests may decrease. Poongothai *et al*. (2013) studied the Cry 1Ac levels and biochemical variations in Bt cotton as influenced by tissue maturity and senescence.

Squares of 18 cotton genotypes were also collected at 90 DAS and 120 DAS. The expression of cry1A and Cry2A toxin was then analysed by using ELISA assay. Results showed that all the cotton genotypes varied from each other with respect to Cry toxin levels. The Cry1A toxin level in squares ranged from 0.186-0.629 ìg/g at 90 DAS and 0.107–0.466 µg/g at 120 DAS. The Cry2A toxin level was found to be *maximally* expressed in the squares of MRC 6304 genotypes at 90 DAS (0.629 ìg/g) and 120 DAS (0.589 ìg/g) whereas Platinum 605 showed the highest level of Cry2A toxin at 90 DAS (0.491 ìg/g) and 120 DAS (0.466 ìg/g). Therefore, it was observed that Cry toxin levels were higher during the initial developmental stages i.e. at 90 DAS and decreased with the passage of time at 120 DAS as also reported by Adamczyk and Sumerford, 2001. This showed that the amount of Cry toxins decreased gradually in squares also as the plants attained maturity. Various factors might be responsible for the varying levels of cry toxin such as variation in gene expression which is due to Bt gene base sequences, copy number, the promoter used and gene incorporation point into the DNA of target Bt varieties. The decrease in Cry1Ac proteins at late developmental stages may be due to low expression of mRNA19 and also due to variations in methylation status of the promoter (35S) region (Xia *et al*., 2005). When leaves and squares were compared, it was observed that the leaves had higher levels of Cry proteins than the squares as reported by Greenplate *et al*., 2000; Kranthi *et al*., 2005 and Manjunatha, *et al*., 2009.

Table 2. Quantification of Bt toxins in square tissues at 90 and 120 days after sowing (DAS)

Genotype	Cry1A		Cry2A	
	90 DAS	120 DAS	90 DAS	120 DAS
RCH 134	0.513±0.005^{a}	0.491±0.002$^{a\,*}$	0.148±0.004^{a}	0.123±0.002$^{a\,**}$
MRC 6304	0.629±0.005^{b}	0.584±0.001$^{b\,**}$	0.417±0.007^{b}	0.372±0.001$^{b\,**}$
Ankur 3028	0.465±0.003^{c}	0.418±0.003$^{c\,**}$	0.341±0.001$^{c\,**}$	0.306±0.002^{c}
SP 7007	0.510±0.002^{a}	0.467±0.002$^{d\,**}$	0.269±0.003^{d}	0.220±0.019^{d}
MRC 7017	0.593±0.002^{d}	0.528±0.003$^{e\,**}$	0.314±0.002^{e}	0.278±0.002$^{e\,**}$
JKCH 1050	0.384±0.003^{e}	0.331±0.003$^{f\,**}$	0.310±0.002^{e}	0.264±0.003$^{e\,**}$
Vibha 1544	0.207±0.003^{f}	0.183±0.003$^{g\,**}$	0.374±0.010^{f}	0.318±0.003$^{c\,*}$
Raja Kribco	0.326±0.004^{g}	0.294±0.002$^{h\,**}$	0.207±0.003^{g}	0.117±0.004$^{a\,**}$
Shakti 9	0.508±0.003^{a}	0.480±0.003$^{i\,**}$	0.394±0.002^{h}	0.344±0.002$^{f\,**}$
Platinum 605	0.616±0.003^{h}	0.581±0.004$^{b\,**}$	0.491±0.003i	0.466±0.002$^{g\,**}$
Jadu	0.198±0.002^{i}	0.123±0.002$^{j\,**}$	0.219±0.002^{g}	0.195±0.003$^{h\,**}$
Vardaan	0.411±0.003^{j}	0.375±0.002$^{k\,**}$	0.389±0.003^{h}	0.350±0.003$^{f\,**}$
Pancham 541	0.364±0.002^{k}	0.309±0.002$^{l\,**}$	0.236±0.002^{j}	0.198±0.002$^{hi\,**}$
Bioseeds 6588	0.386±0.003^{e}	0.356±0.001$^{m\,**}$	0.367±0.005^{f}	0.329±0.002$^{c\,**}$
Bioseeds 6488	0.415±0.002^{j}	0.386±0.002$^{n\,**}$	0.350±0.002^{c}	0.311±0.002$^{c\,**}$
Bunty 2113-2	0.614±0.002^{h}	0.582±0.002$^{b\,**}$	0.556±0.004^{k}	0.401±0.002$^{k\,**}$
Vich 310	0.287±0.002^{l}	0.230±0.002$^{o\,**}$	0.264±0.001^{d}	0.212±0.004$^{ij\,**}$
Vich 309	0.186±0.002^{m}	0.107±0.003$^{p\,**}$	0.271±0.001^{d}	0.214±0.004$^{j\,**}$

a,b,c,d…p: values with different superscripts within a column vary significantly from each other (p<0.05).
*Values differ significantly (p<0.05) between when compared between days 90 and 120.
**Values differ significantly (p<0.01) between when compared between days 90 and 120 separately for each Cry1a and Cry2a.

Genotype MRC 6304 was found to be the top ranker for Cry1A specific crystal protein contents at all stages and in all plant tissues. While for Cry2A the maximum expression was observed in Vich 310 and Bunty 2113-2. The hybrids' performance with regard to Cry 1A and Cry 2A expression remained comparable since the best performing hybrids at different stages and diverse plant parts remained unchanged.

CONCLUSION

The observations of this study have highlighted the fact that Bt expression from Cry 1 A is developmentally regulated and towards the reproductive stage it tends to taper down to only a fraction in all the genotypes. The drop in expression from Cry 2A was relatively less. The genotypes showing high expression during late stage like MRC 6304, Bunty 2113-2, Platinum 605, MRC 7017 and RCH 134 may be more promising to fight out insect attack.

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Productivity and economics of moth bean (*Vigna aconitifolia*) with intercrops under rainfed conditions

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ABSTRACT

A field experiment was conducted at Dryland Research Farm of Chaudhary Charan singh Haryana Agricultural University, Hisar during the rainy season of 2006 to 2009 to find out feasibility of intercrops with moth bean. Results indicated that intercropping of one row of clusterbean in 30:60 cm moth bean paired row system proved superior to other treatments and yielded 258 kg/ha moth bean and 1039 kg/ha cluster bean grain yield, which amounted to 1143 kg/ha moth bean-equivalent yield compared with 718-783 kg/ha under three sole cropping pattern of moth bean. This system also recorded highest net returns (Rs 18319/ha), benefit: cost ratio (2.25), monetary advantage index (2249), income equivalent ratio (1.59) and land-equivalent ratio (1.13). The values of competitive ratio (CR), relative crowding coefficient (RCC) and aggressivity indicated that intercrops were dominant over moth bean. The aggressivity value of moth bean was negative in moth bean+clusterbean intercropping system whereas CR and RCC values remained <1.

Key words : *Vigna aconitifolia,* intercrops, yield, economics, competitive indices

INTRODUCTION

Moth bean (*Vigna aconitifolia*) is a pulse crop generally grown under rainfed conditions. It is a fast growing and has deep root system. It can also be cultivated in adverse climatic conditions. Improved cultivars of moth bean have shown promising results under sub-normal rainfall conditions. The suitable intercropping system might increase the total production through efficient utilization of production factors like space, moisture, nutrients etc. Short duration crops have ample scope to grow with other crops for introducing some compatible intercrops to increase the productivity. Plant population and spatial arrangement in intercropping have an important effect on competition between the component crops and their productivity (Faroda *et.al*, 2007). Therefore, an attempt was made to explore the possibility of raising moth bean under rainfed conditions by studying its potential in various sole planting and intercropping with other important kharif crops.

MATERIALS AND METHODS

A field experiment was conducted during the rainy season of four consecutive years from 2006 to 2009 at Dryland Research Farm of Chaudhary Charan Singh Haryana Agricultural University, Hisar. The soil of the experimental site was sandy loam in texture, low in available nitrogen (202 kg/ha), medium in available phosphorus (16.5 kg/ha), high in available potash content (386 kg/ha) and slightly alkaline in reaction (pH 7.9). Eleven treatments consisting of moth bean sole at 30 and 45 cm, moth bean paired at 30:60 cm, intercropping of 1 row of green gram, cluster bean, pearl millet and castor in moth bean paired row system of 30:60 cm, sole cropping of green gram, cluster bean and pearl millet at 45 cm and sole cropping of castor at 90 cm x 60 cm were tested in randomized block design with 3 replications. A basal dose of 20 kg N+40 kg P_2O_5/ha was applied before sowing of the crops. All the crops were sown on 15 July 2006, 24 June 2007, 26 June 2008 and 17 July 2009. The recommended cultivars ‘RMO

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40' of moth bean, 'Muskan' of greengram, 'HG 563'of clusterbean, 'HHB 67' of pearl millet and 'DCH 7' of castor were used in the experiment. Moth bean was harvested 81 days after sowing (DAS). Intercrops, i.e. green gram, cluster bean, pearl millet and castor were harvested 84, 114 and 72 DAS. Picking of castor was done 3 times, i.e. 120, 150, 180 DAS. The total rainfall received during the crop growth season was 131, 249, 382 and 243 mm during 2006, 2007, 2008 and 2009, respectively. The pooled grain yields of all the crops in sole as well as in intercropping systems were subjected to statistical analysis after conversion into the moth bean-equivalent yield taking into consideration the average market prices of 100 kg grain (moth bean Rs 2875, green gram Rs 3250, clusterbean Rs 1775, pearl millet Rs 725 and castor Rs 1850) and straw (pearl millet Rs 125, cluster bean Rs 154 and others Rs 42) during the study period. The four years mean yield of various intercrops in sole stands was used for computation of competition functions by the following methods suggested by Willey (1979). Land equivalent ratio (LER) = La+Lb, La=Yab/Yaa, Lb = Yba/Ybb where, La and Lb are land equivalent ratio of main and intercrops, respectively. Yaa and Yab are yields of main crop while Ybb and Yba are the yields of intercrops in sole stands and in intercropping, respectively. Income equivalent ratio (IER) = income from both main and intercrops in intercropping system/ income from sole main crop. Monetary advantage index (MAI) = Net returns from combined produce (Rs./ha) x (LER-1)/LER. Aggressivity of main crop (Aab) = {(Yab/Yaa x Zab) - (Yba/Ybb x Zba)} and of intercrop (Aba) = {(Yba/Ybb x Zba) - (Yab/Yaa x Zab)}. Relative crowding coefficient of main crop (Kab) = (Yab x Zba)/(Yaa-Yab) Zab and of intercrop (Kba) = (Yba xZab)/(Ybb – Yba) Zba. Competitive ratio of main crop (Cra) = (LERa/LERb) (Zba/Zab) and of intercrop (Crb) = (LERb/LERa) (Zab/Zba) where Zab, proportion of intercrop area allocated to main crop and Zba, proportion of intercrop area allocated to intercrop.

RESULTS AND DISCUSSION

Yield and equivalent yield of moth bean

Moth bean yield among the entire three sole planting patterns *viz.* 30 cm, 45 cm and 30:60 cm paired row spacing did not differ significantly. However, sole cropping of moth bean at 30 cm spacing had slight advantage over 45 cm and 30:60 cm paired row planting with higher yield gain of 6.1 to 8.9% (Table 1). This may be due to efficient utilization of moisture, nutrients and light in this system. Intercropping of 1 row of green gram/cluster bean/pearl millet/castor in 30:60 cm paired row planting of moth bean significantly decreased the yield of main crop moth bean over sole cropping of moth bean. On an average, the magnitude of reduction in moth bean yield varied from 47.29 to 63.24%. However, productivity of moth bean+cluster bean intercropping system in terms of total as well as moth bean-equivalent yield was higher than sole cropping of moth bean. Among

Table 1. Effect of row spacing and intercrops on grain yield of moth bean

Treatment	Grain yield (kg/ha)				
	2006	2007	2008	2009	Mean
MB (S) 30 cm	1243	607	666	547	765
MB (S) 45 cm	1199	577	621	488	721
MB (PR) 30 : 60 cm	1184	562	606	458	702
MB (PR) 30 : 60 cm+1 row GG	488 (512)	232 (459)	281 (518)	207 (325)	302 (453)
MB (PR) 30 : 60 cm+1 row CB	577 (992)	281 (1065)	325 (1139)	251 (962)	258 (1039)
MB (PR) 30 : 60 cm+1 row PM	533 (1066)	252 (1110)	296 (1080)	222 (799)	325 (1013)
MB (PR) 30 : 60 cm+1 row CS	622 (533)	296 (676)	326 (444)	236 (400)	370 (513)
Green gram (S) 45 cm	(873)	(607)	(710)	(518)	(677)
Cluster bean (S) 45 cm	(1613)	(1302)	(1361)	1139)	1353)
Pearl millet (S) 45 cm	(1939)	(2087)	1879)	1509)	(1853)
Castor (S) 90 cm	(888)	1287)	(799)	(742)	(929)
LSD (P=0.05)	212	76	83	102	

MB-Moth bean, S-sole, PR-paired row, GG-green gram, CB-cluster bean, PM-pearl millet, CS-castor.
Figures in parenthesis indicate the grain yield of intercrops.

intercrops when sown as sole crop, pearl millet gave highest yield (1853 kg/ha) followed by cluster bean, castor and green gram. Moth bean+cluster bean intercropping system recorded significantly higher moth bean-equivalent yield (1143 kg/ha) than all other treatments (Table 2). On an average, this system gave 45.97, 54.87, 59.19, 30.33, 61.21 and 44.13% higher moth bean-equivalent yield than sole cropping of moth bean at 30 cm, 45 cm, 30:60 cm, moth bean+green gram, moth bean+pearl millet and moth bean+castor treatments, respectively. Cluster bean was more suitable than all other intercrops mainly owing to higher yield advantage of intercropping. Singh *et.al.* (2012) reported similar results in winter maize.

Economics

Intercropping of one row of clusterbean in 30:60 cm moth bean paired row system had significantly higher net returns to the extent of 67.20, 192.40, 126.60 and 172.97% than moth bean+green gram, moth bean+pearl millet, moth bean+castor and sole cropping of moth bean at 30:60 cm, respectively (Table 2). The sole cropping of cluster bean at 45 cm was next highest in respect of net returns. The minimum net returns of Rs 6265/- was recorded under moth bean+pearl millet which were due to lower market price of pearl millet grain. Highest monetary advantage index (2249) and income equivalent ratio (1.59) were obtained with moth bean+cluster bean followed by moth bean+green gram with monetary advantage index of 1173 and income equivalent ratio of 1.22. This indicates that intercropping of cluster bean with moth bean was more productive than sole cropping of the component crops. Corroborative findings have also been reported by Sharma and Singh (2008).

Land-equivalent ratio

Land-equivalent ratio (LER) of various intercrops varied from 1.01 to 1.13 (Table 2). The highest LER values (1.13) were recorded in moth bean+cluster bean which remained superior to other intercropping system. Higher values of LER in moth bean+cluster bean intercropping system reflect development of complimentarily with least competition in this system. Higher land equivalent ratio in intercropping system under rainfed conditions were also reported by Mishra *et. al*, 2001 and Sharma and Singh, 2008.

Competition ratio

The lowest value of competition ratio (0.23) of moth bean was found under moth bean+cluster bean while highest value was found under moth bean+castor (Table 3). Cluster bean showed the highest competitive ratio when intercropped with moth bean while castor showed the lowest competitive ratio. In general, the competitive ability of moth bean with cluster bean was slightly better than other crops.

Table 2. Moth bean equivalent yield and economics of moth bean based intercropping system (pooled data of 4 years)

Treatment	Moth bean equivalent yield (kg/ha)	Net returns returns (Rs./ha)	B : C ratio	MAI	IER	LER
MB (S) 30 cm	783	8509	1.60	-	-	-
MB (S) 45 cm	738	7311	1.52	-	-	-
MB (PR) 30 : 60 cm	718	6711	1.48	-	-	-
MB (PR) 30 : 60 cm+1 row GG	877	10956	1.76	1173	1.22	1.09
MB (PR) 30 : 60 cm+1 row CB	1143	18319	2.25	2249	1.59	1.13
MB (PR) 30 : 60 cm+1 row PM	709	6265	1.44	61	0.99	1.01
MB (PR) 30 : 60 cm+1 row CS	793	8084	1.54	1053	1.10	1.07
Green gram (S) 45 cm	817	9410	1.66	-	-	-
Cluster bean (S) 45 cm	1018	14902	2.03	-	-	-
Pearl millet (S) 45 cm	686	4597	1.30	-	-	-
Castor (S) 90cm	667	4550	1.30	-	-	-
LSD (P=0.05)	122					

MB-Moth bean, S-sole, PR-paired row, GG-green gram, CB-cluster bean, PM-pearl millet, CS-castor,
MAI-monetary advantage index, IER-income equivalent ratio, LER-land equivalent ratio.

Table 3. Competitive ratio (CR), relative crowding coefficient (RCC) and aggressivity in moth bean based intercropping systems (pooled data of 4 years)

Treatment	CR		RCC		Aggressivity	
	Moth bean	Intercrop	Moth bean	Intercrop	Moth bean	Intercrop
MB (PR) 30 : 60 cm+1 row GG	0.32	3.11	0.37	4.10	0.07	-0.07
MB (PR) 30 : 60 cm+1 row CB	0.23	4.17	0.26	6.71	-0.01	0.01
MB (PR) 30 : 60 cm+1 row PM	0.42	2.36	0.42	2.44	0.13	-0.13
MB (PR) 30 : 60 cm+1 row CS	0.47	2.09	0.48	2.50	0.17	-0.17

Relative crowding coefficient

The RCC values of moth bean were lower than that of all the intercrops, indicating the dominance of all the intercrops over moth bean (Table 3). The RCC values of moth bean were <1 in all intercropping systems, indicating that it yielded less than expected. The highest value of RCC of cluster bean was 6.71 in moth bean+cluster bean followed by green gram (4.10) in moth bean+green gram intercropping system. The RCC values of intercrops were always >1. This indicates that all the intercrops yielded more than expected and had better competitive ability than moth bean in the intercropping system.

Aggressivity

The highest value of aggressivity of moth bean was 0.17 under moth bean+castor and lowest value of -0.01 was recorded under moth bean+cluster bean treatment (Table 3). The negative aggressivity of all intercrops except cluster bean indicated the poor competitiveness of intercrops than main moth bean crop which had positive aggressivity in all the intercrops except clusterbean. The positive sign of aggressivity value of clusterbean in intercropping system indicates that cluster bean was dominant as a component crop. The negative sign for moth bean indicates that the component crop was dominated.

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Performance of improved forage species under dry temperate conditions of north Western Himalayas

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ABSTRACT

A field experiment was conducted to study the effect of improved grasses and legumes on the productivity and quality of natural grasslands under dry temperate region of north western Himalayas at Research Sub-Station-Lari (Spiti) of CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur during summer seasons of 2005 to 2007. Planting of improved species significantly improved the herbage yields and quality over local system. Among improved species legumes were better producer than grasses. Lucerne produced 155.7 and 158.0% higher green and dry forage yields than local system. Among improved grasses tall fescue grass proved better than orchard grass. Mixed stand of grasses with legumes was better than sole stand. The mixed stand of tall fescue grass with lucerne produced 128.1 and 127.4% higher green and dry forage yields than local system, respectively. The planting of improved species also had favourable effect on the nutritionally desirable parameters *i.e.*, crude protein, cellulose, hemi cellulose and total ash.

Key words : Orchard grass, Tall fescue grass, Red clover, Lucerne, Green and dry forage yield

INTRODUCTION

The dry temperate region of Himalayas is characterized by low precipitation, low temperature and high snowfall. In this region generally, all the areas excluding the intensively cultivated one are used as pasture and grasslands. In Himalayan region about 1.7 m ha area is occupied by temperate and alpine grasslands (Singh, 1988). By and large the production potential of these pastures and grasslands is only 20-25% of their potential capacity. The farmers of the region, who rear few cattle in integration with sheep and goat, depend on low yielding local species of grasses and legumes for fodder requirement. The area is characterised by sloppy desert mountains with crop growing season of 5-6 months (April to September). The annual snowfall varies from 16.1–343.3 cm. Very high wind velocity in the afternoon and night hours results in heavy soil erosion and soil moisture losses. In the region, due to continuous heavy grazing and lack of management indigenous grass species presently represent the third or fourth stage of degradation.

According to the survey of Planning Commission, Government of India, 12 m ha area is under pastures and grasslands in the country, but in spite of this large acreage, there is a net deficit of 61.1% in green fodder, 21.9% in dry feed residues and 64% in feeds and concentrates (Anonymous 2012). In the country and especially in north western Himalayas, livestock plays a significant role in sustaining the livelihood of people, but in the region all forage resources are hardly enough to meet the forage requirement of even 40-50% of the existing livestock population. Under this situation the planting of ecologically adaptable improved grasses and forage legumes appears to be a viable preposition to increase the forage production and availability in the region. Keeping this in view, the present study was undertaken to study the comparative performance of improved grasses and legume species under dry temperate climatic conditions.

MATERIALS AND METHODS

A field experiment was conducted during summer 2005 to 2007 in the natural grassland conditions of north western Indian Himalayas at Research Sub-Station, Lari (Spiti Valley) of CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur situated at $30^0\ 42'$ N and $70^0\ 37'$E at an elevation of 3244 m amsl. The soil of the experimental site was sandy loam in texture, alkaline

Table 1. Detail of forage species and seed rate used

Forage species	Variety	Seed rate (kg/ha)
Grasses		
Orchard grass	Commet	20
Tall Fescue grass	Hima-4	15
Legumes		
Red clover	PRC-3	12
Lucerne	Anand -3	16

in reaction (pH 7.2), low in available nitrogen (216 kg/ha) and high in available phosphorus (34.6 kg/ha), potassium (480.3 kg/ha) and organic carbon (1.02%). The experiment was laid out in randomised block design with three replications comparised of nine treatments *viz*. no introduction of improved species i.e. local system; planting of orchard grass (*Dactylis glomerata* L.), tall fescue grass (*Festuca arundinacea* Schreb.), red clover (*Trifolium pretense* L.), lucerne (*Medicago sativa* L.), orchard grass+ red clover, orchard grass+ lucerne, tall fescue grass + red clover and tall fescue grass+ lucerne. The experimental site was made free of weed by mechanical means and thereafter, imprioved forages species in sole stand were sown as per treatment through dibbling at a spacing of 30 cm x 30 cm. In mixed stand legumes were sown with grasses in additive intercropping series. The species were sown during May 2005 after the melting of snow in the valley. The season of 2005 was taken as the year of establishment and further two summer seasons of 2006 and 2007 were considered for data observation to draw the inference from the present study. The details of varieties and seed rate of species used are given in Table 1.

The recommended dose of nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O) was 40: 30:15 to local system, 60:60:30 to improved grasses & grasses +legumes and 30:60:30 to improved legumes. Half of the nitrogen and full dose of P and K was applied at the time of sowing as per treatments. The remaining half N was top dressed after one month of sowing. In subsequest years fertilsers were topdressed as per doses. Before the execution of the experiment initial botanical composition of the experimental site was measured. Samples were taken in 2m x 2m square grid from five randomly selected spots. Different species were separated, dried and weighed and per cent proportion of the species was worked out as percentage of the specie to the total weight of the quadrate.

RESULTS AND DISCUSSIONS

Initial species composition of the experimental site:

The experimental site was comprised of grass, legume and weed species (Table 2). The area was mainly dominated by weed species. The proportion of weeds was to the tune of about 63.8%. *Artmisia sp.* was the major dominated weed in the area and was followed by the dominance of *Ephedra gerardiana, Astragalus himalayansis* and *A. candolleanus.* The presence of grass and legumes species was almost equal. Among grass species *Agrostis gigantean, Bromus gracillimus, B. inermis* were the dominant species and among legumes the area was mainly occupied by *Melilotus alba* and *Medicago falcata*.

Table 2. Initial species composition of the experimental site

Species	Per cent composition
Grasses	
Agrostis gigantean	9
Bromus gracillimus, B. inermis	6
Poa alpina, P. versicolour	2
Carex sp., *Dactylis* sp. and *Festuca* sp.	1.2
Legumes	
Melilotus alba, Medicago falcata.	12.4
Cicer microphyllum, Oxitropis laponica, Lindefolia longiflora	5.6
Weeds	
Artmisia sp.	26.1
Ephedra gerardiana	14.1
Astragalus himalayansis, A. candolleanus	14
Sonchus wightianus, Lactuca tatarica, Breea arvensis, Cousinia thomsoni Cuscuta approximata,	5.7
Thymus linearis, Galium argentea Nepeta criostachya, Waldheimia sp., Glabra sp.	3.9

Green and Dry Fodder Yields:

The data on the performance of various species revealed that the planting of improved grasses and legumes either in sole or in mixed stand increased the forage production significantly over local system; however the magnitude of increase was variable with each treatment (Table 3). Datt *et al.* (2012) also reported significant improvement in herbage yield of temperate pastures with the planting of improved species. The data also indicated improvement in herbage production over the years in all the treatments except in red clover, where no increase in yield was noticed with progressive increase in time which indicated low persistency of red clover compared to other species. Among improved grasses, tall fescue grass produced 74.47% more green forage than orchard grass with respective increase of 104.81% in dry forage owing to more dry matter content in tall fescue grass than orchard grass. Among legumes, lucerne produced 141.39 and 131.33% more green and dry forage yields than red clover, respectively, indicating better performance of lucerne with more dry matter content than red clover. The mixed stand of grasses comprised of lucerne as intercrop produced more herbage yield than their respective stands comprised of red clover as intercrop. Overall comparison of the treatments revealed that sole stand of lucerne produced significantly higher green and dry forage yields of 42.32 t/ha and 16.85 t/ha, respectively. Tall fescue grass + lucerne was the next best treatment producing 37.75 t/ha and 14.85 t/ha green and dry forage yields, respectively. This mixed stand of tall fescue grass and lucerne was followed closely by tall fescue grass + red clover and orchard grass + lucerne. Shah and Singh (1989) also reported good establishment, better competitive ability of introduced species with better yield

Table 3. Effect of various treatments on green and dry forage yield (t/ha)

Treatment	Green Forage				Dry Forage			
	2006	2007	Mean	% increase over local system	2006	2007	Mean	% increase over local system
Local system	13.37	19.73	16.55	-	5.63	7.43	6.53	-
Orchard grass	16.50	29.30	22.90	38.4	6.23	10.90	8.57	31.2
Tall fescue grass	21.47	33.80	27.64	67.0	8.50	12.90	10.70	63.9
Red clover	27.47	26.97	27.22	64.5	11.27	10.70	10.99	68.3
Lucerne	33.13	51.50	42.32	155.7	14.43	19.27	16.85	158.0
Orchard grass+red clover	22.70	37.87	30.29	83.0	10.40	14.47	12.44	90.5
Orchard grass+lucerne	25.60	40.80	33.20	100.6	10.60	15.50	13.05	99.8
Tall fescue grass+red clover	27.50	39.87	33.69	103.6	11.70	15.00	13.35	104.4
Tall fescue grass+lucerne	29.80	45.70	37.75	128.1	12.40	17.30	14.85	127.4
CD (P=0.05)	7.74	2.38	5.06	-	3.46	1.40	2.43	-

Table 4. Quality parameter of forage as influenced by different treatments

Treatments	Crude Protein (%)	Cellulose (%)	Hemi-Cellulose (%)	Total ash (%)	ADF (%)*	NDF (%)*	Silica (%)
Local system	8.55	19.60	20.25	7.08	46.20	68.35	2.79
Orchard grass	11.20	20.80	21.60	7.19	42.39	65.41	2.43
Tall Fescue grass	10.70	19.60	20.72	7.05	41.27	62.37	2.15
Red clover	18.45	20.65	21.36	7.15	41.98	60.58	2.14
Lucerne	18.17	21.45	24.51	7.40	40.51	62.50	2.16
Orchard grass+red clover	14.50	22.97	23.42	7.64	40.20	65.24	2.50
Orchard grass+lucerne	13.41	23.25	24.68	7.95	43.21	66.50	2.65
Tall fescue grass+red clover	13.28	21.50	22.50	7.62	42.86	65.15	2.45
Tall fescue grass+lucerne	13.20	23.16	24.50	7.88	42.50	65.50	2.50

*ADF-Acid detergent fibre; NDF-Neutral detergent fibre.

in the existing grassland conditions. The increase in forage yield was minimum with the sole planting of orchard grass over local system.

Forage Quality:

Forage quality of various production systems have been quantified in terms of different parameters and mean of two years have been presented in Table 4. Planting of improved forage species influenced both desirable (crude protein, cellulose, hemi-cellulose and total ash) and undesirable (acid detergent fibre, neutral detergent fibre and silica) quality traits of the produce. Improved species produced the forage with better quality as evident from higher contents of nutritionally desirable parameters and low values of nutritionally undesirable parameters (Table 4). The contents of acid detergent fibre, neutral detergent fibre and silica were higher under local system. Higher values of crude protein content was noticed in sole legumes, and legumes in the mixed stand also contributed in increasing the crude protein content of the produce compared to sole stand of grasses. The values of nutritionally incriminating components like acid detergent fibre, neutral detergent fibre and silica decreased from 46.20 to 40.20, 68.35 to 60.58 and 2.79 to 2.14%, respectively with the introduction of improved species.

The study conclusively indicated that the productivity and quality of dry temperate grasslands of Spiti valley in north western Himalayan region can be maintained on sustainable basis with the planting of ecologically adapted improved grasses and legumes. Tall fescue grass and lucerne appeared most suitable species for the region.

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Conservation agriculture practices for enhancing productivity of cotton-wheat system

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ABSTRACT

Cotton–wheat cropping system is the second most important wheat based system in the South Asia (4.5 M ha) and India (2.6 M ha) and contributes significantly to the food security in the region. Under the conventional method of crop establishment and crop management, the productivity and profit ability of the cotton–wheat system is low because sowing of wheat after cotton is usually delayed due to late picking coupled with time needed for seedbed preparation, resulting in low wheat yield. Therefore, an attempt was made to develop and evaluate the performance (in terms of system productivity, water productivity and profitability) of conservation agricultural technologies (like permanent narrow and broad-bed planting and residue management under zero tillage with relay sowing under different plant spacing) under an irrigated cotton–wheat system. Results indicate that seed cotton yield in the plots under PB-B was higher compared with other treatments. Similarly, plots under PB-B had significantly higher number of spike, spike length, number of grain/spike, test weight and wheat grain and straw yield than remaining treatments. Therefore, it concluded that cotton–wheat system under permanent beds with residue retention under wide spacing and relay sowing of wheat in two pairs per bed increase productivity of system.

Key words : Cotton-wheat system, relay seeding, conservation agriculture

INTRODUCTION

In South Asia, cotton (*Gossypium hirsutum* L.)-wheat (*Triticum aestivum* L.) is a well-established crop production system of the north-western plains of the Indian subcontinent and adjoining areas of Punjab and Sindh provinces of Pakistan. Cotton-Wheat is the second most important wheat based system in south Asia (4.5 million ha) and India (2.6 m.ha) and contribute significantly to the food security in the region (Das *et al.*, 2014). Potential productivity and assured high returns could be realized from the cotton–wheat rotation system (especially after introduction of Bt cotton), which also improves the livelihood of the farmers of the region. The uniqueness of cotton-wheat system is the combination of grain plus cash cropping, which improves the economy of farmers through the cultivation of cotton as an industrial commodity and wheat as a component of food security. However, production of cotton showed a declining trend in the recent years (Mayee *et al.*, 2008). The major constraints encountered are inadequate crop stand due to poor emergence after sowing, seedlings burning due to high temperature at emergence, alkalinity and salinity problems, and increased incidence of pests, *e.g.* boll worms, white fly and jassid and diseases, *e.g.* wilt, root rot and black cutworm (Brar *et al*., 1998). In addition, the conventional production practices resulted in high cultivation cost and inefficient input use. Likewise, in wheat, delay in sowing under conventional agricultural practices due to late cotton harvest caused yield decline because of prevalence of hot winds during March–April (Pathak *et al*., 2003). The optimum time of wheat sowing in these areas is from forth week of October to the second week of November and delay in its sowing causes marked reduction in yield (Bajwa, 2011). Nasrullah *et al.* (2010) found that yield was reduced by 1.0-1.5% per day by delaying optimum sowing date. Wheat sowing after cotton harvesting is generally delayed by about one month beyond the optimum date due to late pickings of cotton, subsequent tillage and field operations prior to wheat sowing.

Early sowing of wheat after cotton without disturbing the cotton crop is possible only by relay cropping of wheat. Seed cotton yield was also significantly higher with relay seeding due to opportunity for one additional picking (Buttar *et al*., 2013). The input use efficiency is decreasing at a faster rate, posing a threat for food security and rapidly engulfing poor and underprivileged population. In many parts of the region, over-exploitation and poor ground water management has led to decreased water table and negative environmental impacts (Saharawat *et al*., 2010). Deterioration of land quality due to different forms of soil degradation and excess residue burning are other pervasive problems in the region (Bhattacharyya *et al*., 2013; Das *et al*., 2013). These factors lead to consideration of conservation agriculture (CA) for sustained productivity, profitability and soil quality (Kassam *et al*., 2011). Conservation agriculture based on following principles: (i) minimizing mechanical soil disturbance and seeding directly into untilled soil to improve soil organic matter (SOM) content and soil health; (ii) enhancing SOM using cover crops and/or crop residues (mainly residue retention). This protects the soil surface, conserves water and nutrients, promotes soil biological activity and contributes to integrated pest management (IPM); (iii) diversification of crops in associations, sequences and rotations to enhance system resilience and (iv) controlled traffic that lessen soil compaction (FAO, 2011). Conservation agriculture based management practices have potential to produce more at less cost, reduce environmental pollution, promote conjunctive use of organics (avoids residue burning), improve soil health and promote timely planting of crops to address issues of terminal heat stress to wheat in the region (Jat *et al*., 2011). Bed planting generally saves irrigation water (Gathala *et al*., 2011), labour consumption without sacrificing crop productivity (Hobbs and Gupta, 2000; Ladha *et al*., 2009). The permanent bed planting technique has developed for higher production, cost reduction and conservation of resources (Lichter *et al*., 2008). The advantages of permanent raised bed planting over conventional zero tillage (ZT with flat planting) are that it saves irrigation water and weeding. However, there is a need for wider scale testing of these new technologies under diverse production systems, as the CA technologies are site specific and therefore appraisal of CA is important to have significant adoption (Ladha *et al*., 2009).

MATERIALS AND METHODS

Site

An experiment on the cotton–wheat cropping system was conducted during 2013–2015 at Research platform of the Borlaug Institute for South Asia (BISA), Ladowal (Ludhiana), Panjab. Geographically, BISA platform is located 20 km east of Ludhiana at $30^{0}99'$ North latitute, $75^{0}44'$ East longitude and at an altitude of 229 metres above mean sea level. The place located in Trans gangetic agro climatic zone and represents the Indo-Gangetic alluvial plains. The climate of the research farm is a sub-tropical climate, with hot, dry to wet summers (June–October) and cool, dry winters (November–April). The mean maximum temperature in June, which is the hottest month of the year, ranges from 40° to 44.8°C, while the mean minimum temperature in the coldest month of January is as low as 1.6°C. Sand storms and ground frost are commonly associated with summer and winter seasons, respectively. The mean annual rainfall is about 696 mm, of which nearly 80% is received during the monsoon period from July to September and the rest during the period between October and May. The mean daily U.S. Weather Bureau Class ‘A’ open pan evaporation value reaches as 6.8 mm in the month of June and as low as 0.32 mm in the month of January. The annual pan evaporation is about 850 mm. Mean relative humidity attains the maximum value (85 to 90% or even more) during the south-west monsoon and the minimum (30 to 40%) during the summer months. The soil (0–15 cm layer), taken after the uniformity trial of the experimental site was sandy clay loam in texture, other properties are presented in Table 1.

Conventional tillage (CT) involved one ploughing each with a cultivator, disc harrow and rotavator, while in ZT, no ploughing was done. Fresh raised-beds were prepared under CT, while in permanent beds, reshaping and planting was done in one go using a raised bed planter in 2011. Cotton residue involved the leaves and tender twigs along with boll husks, while wheat residue was retained as such after harvesting the crop with a combine harvester that removed wheat residues above ~30 cm height. It was observed that about 20 and 30% of the cotton and wheat residues (stover yields), respectively, were retained in all plots.

Experimental details details

The field experiment was conducted with seven treatment combinations arranged ina randomized block design (RBD) with three replications. The treatment details are given in Table 2.

Crop management

Cotton variety Mikki MRC 7017 BG II was sown in May end each according to treatments by Happy seeder during both years and harvested in mid November. Wheat cv. 'HD 2967' was sown by November-end using seed drill at 23 cm row spacing. A seed-cum-fertilizer drill was used for wheat sowing under CT, while a relay seeder was used for sowing under the permanent and ZT sowing. A recommended dose of 150 kg N ha^{-1} from urea, 30 kg ha^{-1} P from Diammonium phosphate and 25 kg K ha^{-1} from murate of potash for cotton, whole dose of P and K and half dose of nitrogen was applied at the time of sowing. The remaining N dose was applied in two equal split after thinning and at flowering stage of cotton. Two per cent solution of potassium nitrate (13:0:45) was sprayed four times at weekly interval from the initiation of flowering in the cotton. Wheat crop was given uniform application of 120:60:40 kg/ha of N, P_2O_5 and K_2O. Half dose of N and full dose of P_2O_5 and K_2O were applied at the time of sowing of wheat. Remaining half nitrogen was applied as top dressing after first irrigation at CRI stage. Tank mix solution ethion (50 EC) and Imidachlopride 200 SL was sprayed once in the standing crop in order to control whitefly and sucking pest in cotton, respectively. Tank mix solution of Algrip 20 WP (metsulfuron) at 25 g ha^{-1} and clodinafop (15 WP) at 400g ha^{-1} was applied to control *Phalaris minor* after 25 days of sowing in wheat crop. Irrigation water was applied based on tensiometer (IRROMETERS) reading.

Measurement of yield and yield attributes

The total weight of seed cotton per plot in all the pickings (four) was expressed as yield in kg ha^{-1}. Number of spikes of wheat were counted from 0.25 m^2 area randomly from four spots in the net plot, averaged and expressed as spikes m^{-2} area. Ten representative spikes were harvested from marked rows. The spike length (cm) was measured from the base of the peduncle (lower spikelet) to the tip of the spikelet. Ten ear heads from sampled plants were randomly selected, threshed and numbers of grains were counted. The average was worked out to obtain the number of grains $spike^{-1}$. A representative sample of grains was taken from the produce of each plot after drying and cleaning and weight of 1000-grains recorded and was expressed in grams. Total biomass of each net plot was harvested, weighed and threshed after drying. The grains were cleaned and sun dried for 3 to 4 days and weight was recorded. Final yield was expressed in kg ha^{-1}.

RESULTS AND DISCUSSION

Seed cotton yield

The seed cotton yield (kg ha^{-1}) of cotton differed significantly due to different treatments, during both the years of study (Table 4). Seed cotton yield was significantly higher under PB-B followed by ZT-B and PN-B during both the years. The minimum values of these traits were registered under PBB-AM. PB-B registered 12.95 and 18.78% increase in seed cotton yield over CT during 2013-14 and 2014-15, respectively. This is because the number of bolls per plant and boll size improved with decreasing competition between plants, which led to increased yield/plant and finally increased yield per unit area. In wider spacing competition for moisture, light and nutrient also decreased which might have helped in better translocation of photosynthates. Similar results were also found by Ahmed *et al.* (2013) who stated that wider spacing caused significant increase in sympodial branches, total number of bolls per plant, seed cotton weight per plant. Bed planting systems for cotton crop provided enough space between the plants seeded on the top of the beds which help in mechanical weed control (Sayre, 2003, Handbook of Agriculture, 1999). Cotton sown on permanent beds has better crop growth, higher lint yield, and superior fibre quality than cotton sown after conventional tillage (Hulugalle *et al.*, 2005). Seed cotton yield was also significantly higher with relay seeding due to opportunity for one additional picking. Similar results were also found by Buttar *et al.*

Table 1. Physical properties of soil at the experimental site

Treatments	Bulk density (g/cm^3)	Hydraulic conductivity (mm/hr)	Infiltration (mm/ha)	O. C (%)	pH	EC	N	P	K
PN-B	1.47	13.00	15.63	0.44	8.1	0.25	126.3	9.3	150.9
ZT-N	1.48	13.08	15.00	0.43	8.1	0.24	132.6	10.0	151.6
CT	1.58	11.78	14.80	0.38	8.2	0.19	107.5	9.3	134.5
ZT-B	1.48	12.60	15.20	0.43	8.2	0.17	126.1	9.3	149.6
PB-B	1.46	13.05	16.60	0.44	8.2	0.20	133.8	10.7	153.6
PBB-A	1.45	13.92	16.60	0.40	8.2	0.27	131.1	10.0	151.6
PBB-AM	1.46	13.87	15.66	0.46	8.2	0.22	134.7	10.7	153.8

(2013). In CT, the lower seed cotton yield was due to the presence of immature bolls, which remained unopened on the plants at the time of last picking. However, in the case of relay planting treatments, majority of immature bolls were fully open by the time of pulling out of cotton stalks and thus provided more seed cotton yield (Buttar *et al*. 2013).

Wheat yield and yield attributes

The yield attributes, *viz.* number of spikes m^{-2} , spike length, number of grains $spike^{-1}$and test weight of wheat were influenced significantly by conservation agriculture practices during both the years of study (Table 3). Number of spikes was significantly higher under PB-B in both the years, which was significantly higher than CT, ZT-N, PBB-A and PBB-AM in year 2013-14 and in year 2014-15 it was also significantly higher than ZT-N other than aforesaid treatments. Significantly, higher number of grains $spike^{-1}$was observed under PN-B (65.76 and 66.15 during2013-14 and 2014-15, respectively) compared to other treatments but it was statistically at par with PB-B during both the years and minimum number of grain $spike^{-1}$ under CT (55.53 and 57.20 during 2013-14 and 2014-15, respectively) treatment. The crop season data presented in Table 3 indicates that spike length was significantly more under PN-B (11.38 cm and 11.52 cm) followed by PB-B (11.17 and 11.31cm) and PBB-AM (11.07 and 11.26 cm) and lowest was recorded under CT (8.60 and 8.87 cm) during both the years, respectively. Similarly, test weight was also highest under PN-B and lowest in CT during both the years of study. Maximum grain yield was recorded under PB-B (5165.84 and 5314.31 kg ha^{-1} during 2013-14 and 2014-15, respectivley), which was significantly higher to rest of the treatments and lowest yield was observed under CT (3428.47 and 3546.77 during 2013-14 and 2014-15, respectively). The straw yield of wheat was maximum under PB-B, which remained significantly higher than rest of the treatments, except ZT-B. The minimum values of straw yield was registered under CT. Spike density was significantly higher in relay seeding compared with CT. Reduction in spike density in wheat sown after cotton harvest might be attributed to low temperature under delay in sowing. Each stage of development was progressively reduced with delay in sowing, which reduced spike density (Khan and Khalq, 2005). A lower number of grains $spikes^{-1}$ in the crop sown after cotton harvest (CT) was attributed to a higher temperature at anthesis and grain development stages and less time for grain formation as compared with wheat relayed (PB-B) in cotton (Khan and Khaliq, 2005). The relay-seeded wheat crop passed through all growth stages at normal temperature optima and each development stage was completed in normal duration that resulted in a greater number of grains $spikes^{-1}$. Average grain weight of wheat sown after cotton harvest (CT) was lower compared with that of wheat relayed in cotton. These results are in accordance with those of Khan and Khaliq (2005) and Buttar *et al.*2013. Green *et al.* (1985) and Jan *et al.* (2000) reported that 1000-grain weight decreased significantly with delay in sowing. The early sowing of wheat by about 30 days under relay seeding compared with CT increased the spike density and the number of grains $spikes^{-1}$ compared with CT leading to higher wheat yield. This is consistent with the observation made by Khan and Khaliq (2005), who reported 69.4% higher grain yield from relay planting of wheat by surface seeding compared with CT after cotton harvest. Yadav *et al.*, (2005) reported that ZT led

Table 2. Treatment details

Treatment notations	Treatment description							
	Cotton				Wheat			
	Tillage practices	Bed type	Residue retention	Row to row spacing	Tillage practices	Bed type	Residue retention	Row to row spacing
PN-B	Zero tillage	FIRBS	Yes, about 30% of wheat rsidue	67.5	Zero tillage	FIRBS	Yes, about 30% of wheat rsidue	Relay sowing (2 rows per bad)
ZT-N	Zero tillage	Flat	Yes, about 30% of wheat rsidue	67.5	Zero tillage	Flat	Yes, about 30% of wheat rsidue	Relay sowing (2 rows between 2 cotton rows)
CT	Conventional	Flat	No	67.5	Conventional	Flat	No	Conventioanl sowing
ZT-B	Zero tillage	Flat	Yes, about 30% of wheat rsidue	102	Zero tillage	Flat	Yes, about 30% of wheat rsidue	Relay sowing 4 rows between 2 cotton rows)
PB-B	Zero tillage	FIRBS	Yes, about 30% of wheat rsidue	102 (planting on top)	Zero tillage	FIRBS	Yes, about 30% of wheat rsidue	Relay sowing (2 paid bed)
PBB-A	Zero tillage	FIRBS	Yes, about 30% of wheat rsidue	102 (planting on corner)	Zero tillage	FIRBS	Yes, about 30% of wheat rsidue	Relay sowing (3 rows per bad)
PBB-AM*	Zero tillage	FIRBS	Yes, about 30% of wheat rsidue	102 (Yes, about 30% of wheat rsidue	Zero tillage	FIRBS	Yes, about 30% of wheat rsidue	Relay sowing (3 rows per bad)

*Mung bean also included.

Table 3. Effect of sustainable intensification practices on number of spikes, spike length, number of grains/spike and test weight of wheat

Treatments	No. of spikes (m^{-2})		Spike length (cm)		No. of grains/spike		Test weight(g)	
	2013-14	2014-15	2014-14	2014-15	2014-14	2014-15	2014-14	2014-15
PN-B	405.66	411.24	11.38	11.52	65.76	66.20	42.24	42.56
ZT-N	389.50	391.67	10.86	10.93	61.95	62.62	41.20	41.30
CT	323.37	325.42	8.60	8.87	55.53	57.20	35.33	36.90
ZT-B	421.61	428.65	10.85	10.86	62.35	63.03	41.30	41.50
PB-B	431.15	441.00	11.17	11.31	65.53	66.15	42.17	42.38
PBB-A	396.43	407.45	11.04	11.15	63.90	64.20	41.89	42.10
PBB-AM	400.72	408.31	11.07	11.26	63.98	64.21	41.91	42.15
SEm±	5.35	6.17	0.09	0.10	0.12	0.14	0.16	0.17
LSD (P=0.05)	16.68	19.23	0.29	0.33	0.38	0.43	0.49	0.53

Table 4. Effect of sustainable intensification practices on yield (kg ha^{-1}) and harvest index is not given cotton yield of wheat

Treatments	Seed cotton yield (kg ha^{-1})		Grain yield (kg ha^{-1})		Straw yield (kg ha^{-1})	
	2013	2014	2013-14	2014-15	2013-14	2014-15
PN-B	2927.2	2516.0	4568.27	4705.89	6823.19	7295.71
ZT-N	2889.4	2386.8	4265.80	4344.81	6228.78	6877.67
CT	2815.5	2367.8	3428.47	3546.77	5339.75	5737.32
ZT-B	2958.9	2559.7	4877.56	4966.83	7248.21	7477.76
PB-B	3180.1	2812.6	5165.84	5314.31	7498.67	7644.46
PBB-A	2708.6	2116.8	4327.89	4378.38	6416.36	6904.37
PBB-AM	2473.0	2091.9	4403.63	4512.61	6529.15	7007.31
SEm±	112.1	98.9	90.48	97.08	82.25	91.62
LSD (P=0.05)	348.0	304.7	278.75	299.09	256.47	282.28

to improvement in growth and yield attributes, *viz.* plant height, effective tillers, grains/ear and 1000-grain weight due to better establishment of plants as a result of less weed competition under ZT. Similar values of yield attributes under CT and ZT were reported by Singh (2000). Singh *et al.* (2007) also found that wheat performed well under bed planting. Kumar and Yadav (2005) and Gupta *et al.* (2007) reported that yields performance of wheat was marginally better under ZT practices, this could be due to various favourable factors under ZT like proper placement of the seed in the narrow slit made by zero-seed drill, early emergence of wheat seedlings and availability of higher moisture content, which might helped the crop to compete with the crop sown under CT practices.

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Effect of sowing time and seed rate on phenological and morphological response of chickpea cultivars

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ABSTRACT

Phenological and morphological response of four chickpea cultivars (H09-23, H08-18, C-235 and HC-1) to two dates of sowing (1st fortnight of November and December) and three seed rates (40, 50 and 60 kg ha^{-1}) were studied at Pulse Research Area of CCS Haryana Agricultural University, Hisar during *rabi* 2012-13. The experiment was laid out in a split plot design with two sowing time and four cultivars in the main plots while three seed rates were kept in subplots and replicated thrice. Sowing chickpea on 1st fortnight of November resulted in early emergence of seedling (by two days) as compared to delayed sowing. It took significantly higher number of days to attain 50 % flowering, 50 % podding and maturity as compared to delayed sowing. Early sowing in 1st fortnight of November resulted in 22.4% higher dry matter production,15 % increased plant population at 15 DAS, 12.6 % increase in plant population at harvest, 31 % higher pods/ plant and significantly taller plants as compared to delayed sowing . Chickpea cultivar H09-23 took significantly less number of days to maturity followed by C235, HC-1 and H08-18. The H09-23 showed superiority in dry matter accumulation per plant, number of pods and taller plants. Seed rate of 60 kg ha^{-1} resulted in 14 % increase in plant population at harvest as compared to lower seed rate (40 kg ha^{-1}). However, seed rates at 40 kg ha^{-1} produced 12.5% higher number of pod per plant than with 60 kg ha^{-1} seed rate.

Keywords : chickpea, seed rate, sowing time, cultivars, phenology, growth

Chickpea (*Cicer arietinum* L.) is the most important *rabi* pulse crop. In India, it accounts for more than one third of the area and about 50% of the production of pulses. India accounts for 65% of the world acreage and 67% production of chickpea. Dried chickpea seed is commonly used in soup in India, while in the Middle East and elsewhere it is more frequently cooked and blended with rice dishes. Despite its economic and nutritive importance, the yield of chickpea is very low in India. There are many factors responsible for the low yield. The use of traditional or low yielding varieties and adoption of poor management practices are of great importance. Amongst the agronomic practices, sowing methods and proper seed rate are of great importance (Reddy *et al*., 2003). Since very little scope exists for horizontal growth, the alternative seems by achieving vertical growth through increasing its productivity level. Thus, there is a need to adopt suitable management practice like proper sowing time and to use high yielding varieties. Sowing date is one of the most important agronomic factors affecting chickpea productivity (Saxena, 1987). It is an important non-cash input which has been recognized as the most critical factor in influencing its yield. Sowing of chickpea at optimum time ensures a better harmony among soil, plant and atmospheric system. Studies have shown that early winter sowing (mid-October to mid-November) is the optimum period (Saxena, 1987; Papendick *et al.*, 1988). Late sowing, after November 18 reduced yield by 28 % for every 10 day interval delay (Paikaray and Misra, 1992). Keeping in view, the scanty information available on these aspects, present investigation entitled, “Effect of sowing time and seed rate on phenological and morphological response of chickpea cultivars” was carried out.

The study was conducted at Pulse Research Area of CCS Haryana Agricultural University, Hisar during rabi season of 2012-13 on sandy loam soils under irrigated conditions. The factorial experiment consisting of 24 treatment combinations with two sowing time (1st fortnight of November and 1st fortnight of December) and four cultivars (H09-23, H08-18, C-235 and HC-1) kept in main plots while three seed rates *viz*. 40, 50 and 60 kg/ha in split plot design with three replications. The crop was sown with a row spacing of 30 cm as per the dates of sowing. The fertilizer was applied in the form of di-ammonium phosphate. The soil of the experimental site was deep sandy loam having a pH of 7.9, EC of 0.13 dS/m and low in organic carbon (0.34%), low in available N status (193.36 kg/ha), medium in available P_2O_5 (32.18 kg/ha) and high in available K_2O (249.67 kg/ha). The crop was irrigated as and when required so as to maintain adequate soil moisture in the root zone The crop was sprayed with monocrotophos (1.25 l/ha) at the initiation of flowering and at pod filling stage to protect the crop from pod borer attack. Number of days taken for emergence of seeds was visually recorded for each treatment. Visually flowering and podding appear once in 50 % plants, days to flowering and podding were recorded for each sowing date and cultivars. The morphological traits like plant population, plant height, dry matter accumulation and number of pod per plant were recorded on three randomly selected plants.

Phenological stages

Effect of sowing dates : Perusal of data in Table 1 indicates that the number of days to emergence of coleoptiles is significantly more with the delay in sowing. Chickpea sown on 1st fortnight of November took significantly higher number of days for the emergence of coleoptiles, 50 % flowering, 50 % podding and maturity as compared to delayed sowing.

Performance of chickpea cultivars : A close perusal of the data in Table 1 reveals that cultivars differed significantly with each other in respect of number of days taken to various phenological stages. Cultivar H09-23 emerged significantly earlier than H08-18 and C235; however, it was at par with HC-1. Cultivar C235 took significantly higher number of days to 50 % flowering and 50 % podding than other cultivars. H09-23 took significantly less number of days to maturity followed by C235, HC-1 and H08-18. Maximum and minimum number of days for 50 % flowering and 50 per cent podding were recorded with cultivar C235 and H09-23, respectively. The variations in the time taken to reach these stages by various cultivars might be attributed to the differences in their genetic makeup. These results are in agreement with the findings of Ihsanullah *et al.* (2002) who observed variation in days taken to emergence, 50 % flowering and physiological maturity in mash bean for different varieties.

Effect of seed rates : Differences among various seed rates in terms of days taken to different phenological events are not visible (Table1). However, days taken to 50 % flowering were delayed by two days when seed rate was reduced to 40 kg/ha from 60 kg/ha. Similar results of seed rates on the phenophasic development of chickpea cultivars have been reported by Prasad (2009).

Morphological trait

Effect of sowing dates : The data depicted in fig 1, fig 2 and fig 4 indicate that sowing chickpea in the 1st fortnight of November resulted in 15 % increase in plant population recorded at 15 DAS and 12.6 % increase in plant population at harvest, 31 % higher pods/plant and significantly taller plant as compared to delayed sowing which might be due to the most congenial environment available throughout the crop period during this date of sowing. With the delay in sowing, significant reduction in plant height was observed which might be due to delayed germination and early maturity of the crop. Prasad (2009) and Yadav *et al.* (1998) also reported the reduction in plant height with delayed sowing.

Early sowing in the 1st fortnight of November resulted in 22.4% higher dry matter production as compared to 1st fortnight of December sowing (fig 3). This is in complete agreement with the findings of Saini *et al.* (1996). However, Dixit *et al* (1993) reported that November 16th sowing of chickpea produced higher dry matter production, pods per plant and grain yield. Similar results were reported by Prasad *et al.* (2012).

Performance of chickpea cultivars : Plant population at all the stages did not differ significantly due to chickpea cultivars (Fig 1). However, plant height was significantly affected from 30 DAS onwards up to crop harvest. H09-23 produced significantly taller plants than all cultivars (H08-18, C235 and HC-1) (Fig 2).This is in agreement with the findings of Bahal *et al.* (1984). Among different cultivars, H09-23 showed the superiority in dry matter accumulation per plant and accumulated highest dry matter as compared to other cultivars throughout the crop growing season (Fig 3). Maximum numbers of pods were recorded in H09-23 and least by the cultivar C235 (Fig 4).

Effect of seed rates : Seed rate of 60 kg ha^{-1} resulted in 15.8 % increase in plant population at 15 DAS

Table 1. Effect of sowing time and seed rate on different phenological stages of chickpea cultivars

Treatments	Phenological events (Days)			
	Seedling emergence	50% flowering	50% podding	Maturity
Sowing time				
1st fortnight of November	11.5	99.2	114.8	139.2
1st fortnight of December	13.6	82.1	105.9	135.5
SEm ±	0.259	0.679	0.378	0.827
CD at 5%	0.785	2.06	1.15	2.507
Cultivars				
H08-18	12.5	90.9	109.3	140.5
H09-23	11.7	87.3	103.3	133.7
C235	13.7	93.5	115.8	136.7
HC-1	12.4	90.7	112.9	138.6
SEm ±	0.366	0.960	0.535	1.169
CD at 5%	1.11	2.91	1.622	3.546
Seed rates				
40 kg ha^{-1}	12.6	89.6	110.7	137.5
50 kg ha^{-1}	12.4	90.6	110.1	137.9
60 kg ha^{-1}	12.7	91.6	110.2	136.7
SE m ±	0.252	0.805	0.224	0.389
C. D. at 5%	NS	NS	NS	NS

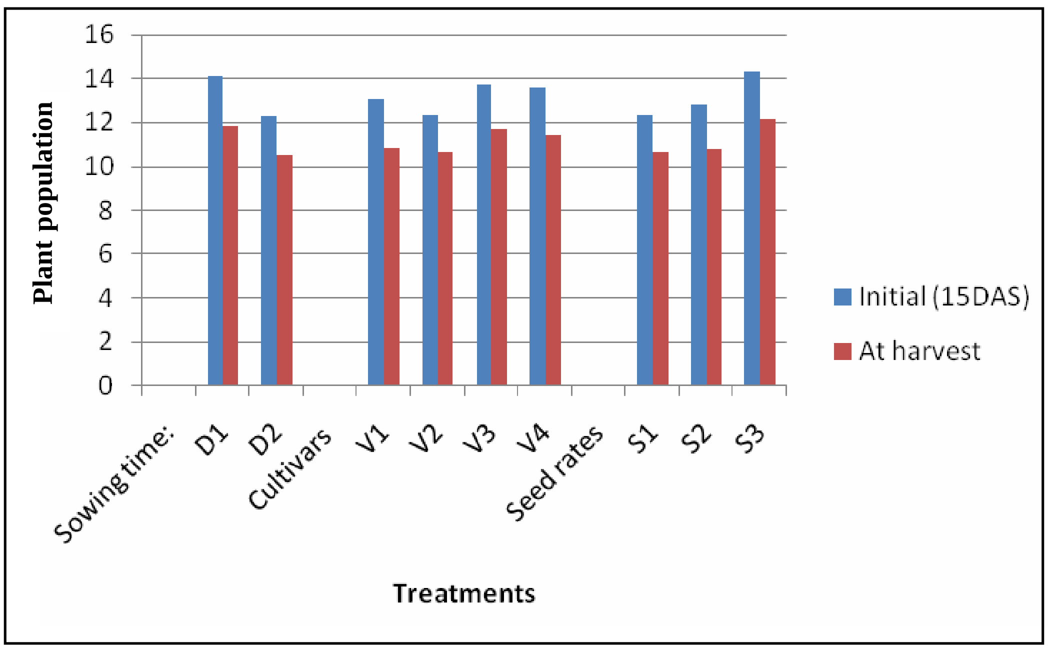

Fig. 1. Effect of sowing time and seed rate on plant population/meter row length of chickpea cultivars.

and 14 % increase in plant population at harvest as compared to lower rate (40 kg ha^{-1}) (Fig 1). Comparatively taller plants at 90 DAS were recorded with 50 and 60 kg/ha seed rates. But, it remained non-significant at 30, 60,120 DAS and at maturity (Fig 2). Similar were the findings of Sarwar (1998) and Hussain *et al.* (1998). Dry matter accumulation of chickpea cultivars were not influenced by seed rate during the entire crop growing season. Maximum numbers of pods per plant were produced with seed rate of 40 kg/ha which was

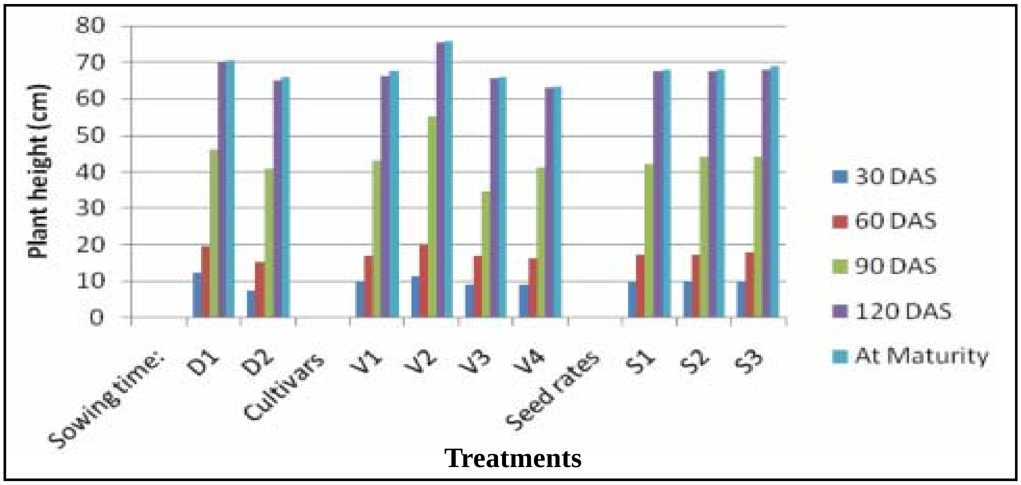

Fig. 2. Effect of sowing time and seed rate on plant height (cm) of chickpea cultivars.

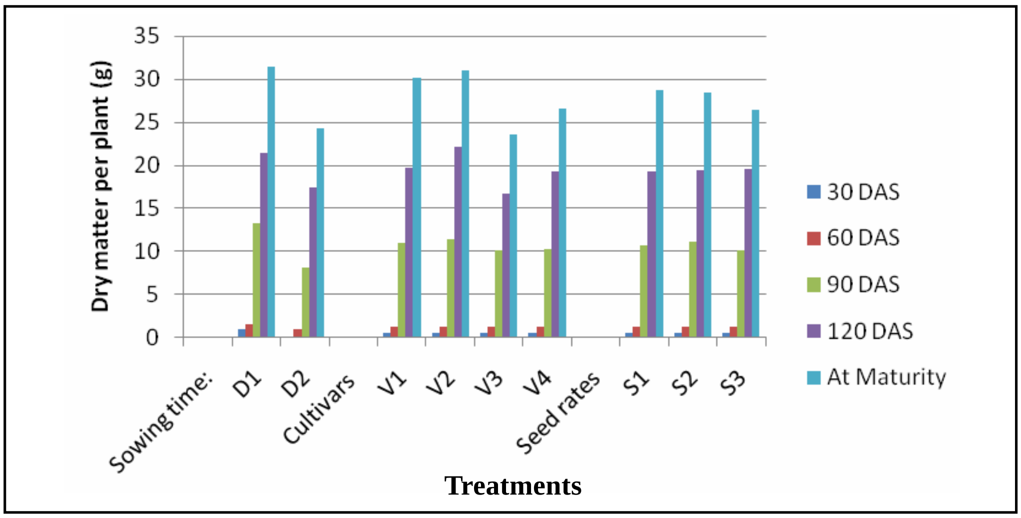

Fig. 3. Effect of sowing time and seed rate on dry matter accumulation per plant (g) of chickpea cultivars.

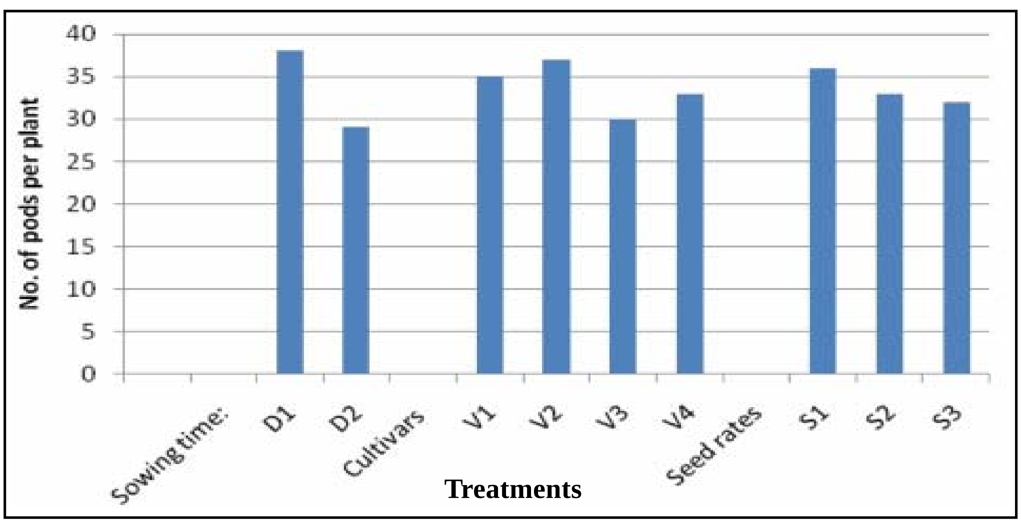

Fig. 4. Effect of sowing time and seed rate on number of pods per plant of chickpea cultivars.

significantly higher than other two seed rate (Fig. 4).

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Effect of nitrogen, phosphorus and cutting management on yield and quality of oat (*Avena sativa L.*)

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ABSTRACT

Results obtained from the field experiment on oat crop recorded highest fodder yield when crop was cut at 70 days after sowing (DAS) followed by cut at 60 DAS and least by 50 DAS. Highest grain yield was recorded when oat was cut at 60 DAS (28 .06 q ha^{-1}) followed by cut at 50 DAS (25 .57 q ha^{-1}) and lowest by cut at 70 DAS (23.93 q ha^{-1}). However, straw yield was recorded maximum under treatment, cut at 50 DAS (65.46 q ha^{-1}) followed by at 60 (63.68 q ha^{-1}) and least at 70 DAS (55.40 q ha^{-1}). Application of nitrogen and phosphorus significantly increased dry fodder, grain and straw yield of oat from 21.27, 21.92 and 57.01 to 42.54, 29.37 and 66.40 q ha^{-1}, respectively, with N_{120}+P_{60} over no N and P, N_{40}+P_{20} and N_{80}+P_{40} treatments. Crude protein in fodder decreased significantly with increase in age of crop and decrease was from 13.51% at cut 50 DAS to 12.64% 12.51 at cut 60 DAS and 11.77% at cut 70 DAS. Application of N and P N_{120}+P_{60} significantly increased crude protein in fodder, grain and straw from 11.61, 8.85 and 2.17 to 13.65, 9.32 and 2.33%, respectively over control (no N and P), N_{40}+ P_{20} and N_{80}+P_{40} treatments.

Key words : Fodder, grain, straw, yield, crude protein content, DAS per cent q ha^{-1}

INTRODUCTION

India is having the largest livestock population of 520 million heads, which is about 15 % of the world's livestock population. But, the country is having only 4.4 % of the cultivated area under fodder crops with an annual total forage production of 833 m t (390 m t green and 443 m t dry forage). Whereas, the annual forage requirement is 1594 m t (1025 m t green and 569 m t dry) to support the existing livestock population. The present feed and fodder resources of the country can meet only 52.26 % of the total requirement, with a vast deficit of 61.95 % and 22.14 % of green and dry fodder, respectively (Anonymous, 2009). Oat (*Avena sativa L.*), locally known as 'jai' is an important non-legume, winter cereal crop, grown under irrigated conditions of northern and north-western regions of India because of its excellent growth characters, quick regrowth and economic source of dietary energy like other multi cut fodders. It provides succulent and highly palatable fodder in two to three cuttings extending from December to February. Oat fodder can also be converted into hay or silage for feeding the animals during lean period. Like barley, oat grain is also used in processed food like biscuits, breakfast cereals etc. This food is low in saturated fat, and very low in cholesterol and sodium. It is also a good source of dietary fiber, thiamin, magnesium and phosphorus, and a very good source of manganese Arora (2014). Nitrogen and phosphorus are the major essential nutrients which may be able to play a major role in improving the quality and yield fodder crop like oat. Main constraint in achieving proven crop potential is imbalanced use of fertilizers, particularly low use of P as compared to N (Rashid *et al.* 2007). The optimum rates of P application play a vital role in improving yields of most crops. Therefore, we need to find out the nutritional requirement of oat crop for harvesting good yield.

MATERIALS AND METHODS

To study the effect of N, P and cutting management on yield and quality of oat grain and fodder yield experiment was conducted at the Forage research farm of CCSHAU, Hisar during rabi 2012-13. Oat var. HJ 8 was taken as test crop. Hisar is situated in the semi-arid, sub tropics at $29^0$17' N latitude and $75^0$77' E longitude at an altitude of 215.2 m above msl. The soil of the field is derived from Indo-Gangetic alluvium and is sandy loam in texture. The details of physical and chemical properties of the experimental along with the methods followed is given in Table 1. Four fertility levels (F_0=control, $F_1=N_{40}+P_{20}$, $F_2=N_{80}+P_{40}$ and $F_3=N_{120}+P_{60}$) and three cuttings (C_{50} = first cut 50 DAS, C_{60} = second cut 60 DAS and C_{70} = third cut 70 DAS) were maintained. After cutting, crop was left for grain production. The green fodder was harvested 8-10 cm above the ground level as per treatment. Then the crop was managed for grain production. Gross plot size was 5 m x 3 m = 15 m^2 and net plot size was 4 m x 2.5 m =10 m^2. Experiment was laid out in factorial randomized block design (FRBD). Each of 12 treatment combination was randomly allotted to individual plot in block of equal size. The treatments were replicated thrice. The details of the treatments are given in Table 2. Nitrogen and phosphorus were applied through urea and single super phosphate as per the treatments. All the field operations such as hoeing, irrigation etc were done as and when required. The harvested green fodder from each plot was weighed *in situ* on salter balance in kg $plot^{-1}$ and then green fodder yield q/ha was calculated. A random sample of 500 g was taken from each plot at the time of green fodder harvesting, chopped well and put into the paper bag. These paper bags were aerated by making small holes all over. The samples were first dried in the sun for several days and then transferred in an electric hot air oven for drying at a temperature of 70±5^{0}C till constant weight. On the basis of these samples the green fodder yields were converted into dry fodder yields q ha^{-1}. After recording the sun dried weight of biological yield obtained from each net plot, the grains were separated and weighted. The grain yield was subtracted from the total biological yield to obtain straw yield. Later on grain and straw yields per hectare were calculated.

RESULTS AND DISCUSSIONS

Dry fodder, grain and straw yield

The data (Table 2) indicated that the significant and highest dry fodder yield was recorded when oat was cut at 70 DAS (35.70 q ha^{-1}) followed by cut at 60 DAS (31.90 q ha^{-1}) and cut at 50 DAS (28 .50 q ha^{-1}). Joon *et al*. (1993) reported that green and dry fodder yield increased significantly when oat was harvested at 75 DAS compared with that harvested at 55 DAS. Singh (2004) reported that cutting at 70 DAS recorded maximum accumulation through leaf and stem. In case of grain yield of oat, significantly and highest grain yield was recorded when oat was cut at 60 DAS (28 .06 q ha^{-1}) followed by cut at 50 DAS (25 .57 q ha^{-1}) and lowest grain yield was recorded when oat was cut at 70 DAS (23.93 qha^{-1}). However, straw yield was recorded maximum under C_{50} treatment (65 .46 qha^{-1}) followed by C_{60} (63. 68 q ha^{-1}) and least by C_{70} treatment (55. 40 q ha^{-1}). Hence it can be further revealed that harvesting of fodder at C_{60} gave higher grain yield but lesser fodder yield while harvesting fodder at C_{70} gave higher green and dry fodder yield but less grain and straw yield. Therefore harvesting the crop for fodder at C_{60} found better to strike a balance between fodder and grain yield which gave higher returns. Similar observations were made by Patel *et al*. (2011) and Jehangir *et al*. (2013).

Data further indicated that the dry fodder, grain and straw yield of oat increased significantly with the increase in each successive dose of N and P. The increase was from 21.27, 21.92 and 57.01to 27.47, 24.83 and 63.00 q ha^{-1}, respectively with F_1 over F_0. The treatment F_2 further improved it from 27.47, 24.83 and 59.64 to 36.86, 27.30 and 63.00 q ha^{-1}, respectively over F_1. The highest and significant dry fodder, grain and straw yield

Table 1. Physical and chemical properties of soil of experimental field before sowing of oat

Property	Values	Method used
Sand (%)	60.48	International Pipette method (Piper, 1966)
Silt (%)	18.90	
Clay (%)	20.62	
Organic carbon (%)	0.34	Walkley and Black wet oxidation method (1934)
Soil pH	7.9	Glass electrode pH meter (Jackson, 1973)
EC (dSm^{-1} at 25 ^{0}C)	0.13	Conductivity bridge meter
Available nitrogen (mg kg^{-1})	96.68	Alkaline per magnate method (Subbiah and Asija, 1956)
Available phosphorus (mg kg^{-1})	6.09	Olsen’s method (Olsen *et al.*, 1954)
Available potassium (mg kg^{-1})	124.83	Flame photometer method

of oat were obtained with F_3 42.54, 29.37 and 66.40 q ha^{-1} respectively over F_0, F_1 and F_2. Sharma (2009), Rana *et al*. (2009), Rawat and Agrawal (2010), Patel *et al*. (2010) and Sheoran and Joshi (2010) also reported similar results.

Crude protein content

The data related to crude protein in fodder (%), in grain (%) and in straw (%) are presented in Table 3. The data revealed that crude protein in fodder decreased significantly with increase in age of crop and decrease was from 13.51 % at cut at 50 DAS to 12.64 % 12.51 at cut 60 DAS and 11.77 at cut at 70 DAS. However, crude protein content in grain and straw was found to be nonsignificant under various cutting management treatments.

Crude protein content in fodder, grain and straw were found lowest (11.61, 8.85 and 2.17%, respectively) under F_0 (no N and P) treatment and with increase in fertility levels there was significant increase in crude protein content and highest values (13.65, 9.32 and 2.33%, respectively) were recorded under highest fertility level (120 kg N + 60 kg P_2O_5 ha^{-1}). Rana *et al*. (2009) and Devi *et al*. (2010) also reported similar results.

4.1.12 IVDMD and DDM

The data given in Table 3 indicate that in vitro dry matter digestibility (IVDMD) in fodder was found maximum (68.48 %) under C_{50} treatment and it decread with each delay in fodder cut and the lowest IVDMD (62.98 %) was found when fodder was cut at 70 DAS. Data further indicated that differences between different fertility levels were non significant with respect to IVDMD in fodder. However, DDM (q ha^{-1}) increased significantly with each successive increase in fertility level upto the highest level *i.e* F_3 treatment and increase was from 13.85 to 27.56 q ha^{-1} over F_0, F_1 and F_2, respectively.

Table 2. Effect of cutting management and fertility levels on dry fodder, grain and straw yield (qha^{-1})

Cutting management	Fodder (Dry) yield	Grain yield	Straw yield
First cut	28.50	25.57	65.46
Second cut	31.90	28.06	63.68
Third cut	35.70	23.93	55.40
LSD (P=0.05)	1.51	1.47	3.75
Fertility levels			
F_0	21.27	21.92	57.01
F_1	27.47	24.83	59.64
F_2	36.86	27.30	63.00
F_3	42.54	29.37	66.40
LSD (P=0.05)	1.74	1.70	2.33

Table 3. Effect of cutting management and fertility levels on crude protein content in fodder, grain and straw

Cutting management	C. P in fodder (%)	C.P in grain (%)	C.P in straw (%)	IVDMD (%)	DDM (q/ha)
First cut	13.51	9.13	2.28	68.48	19.44
Second cut	12.64	9.12	2.23	64.99	20.73
Third cut	11.77	9.06	2.27	62.98	22.48
LSD (P=0.05)	0.32	NS	NS	1.22	1.20
Fertility levels					
F_0	11.61	8.85	2.17	65.53	13.85
F_1	12.27	9.14	2.25	66.12	18.09
F_2	13.05	9.11	2.29	65.46	24.05
F_3	13.65	9.32	2.33	64.83	27.56
LSD (P=0.05)	0.36	0.20	0.06	NS	1.39

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Effect of time and mode of nitrogen application on quality, yield and yield attributes in cluster bean (*Cyamops tetragonoloba* L.)

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ABSTRACT

Results from the field experiment revealed that the application of N @ 20 kg ha^{-1} as a basal dose significantly increased the number of pods per plant from 45.32 to 48.13 over control. Split application of N, 10 kg ha^{-1} as basal dose and 10 kg ha^{-1} as top dressing at first irrigation further increased the pods number to 52.80. Highest (53.18) number of pods per plant were observed with 1 % urea spray at vegetative and flowering stage. Treatments 10 kg N ha^{-1} as basal dose + 1 % urea spray at flowering recorded the highest number of seeds per pod (9.03). Lowest (7.73) number of seeds per pod were recorded by the control. Maximum pod length (6.23 cm) recorded with 1 % urea spray at vegetative and flowering stage. Maximum 100 seed weight (3.29 g) was recorded with 10 kg N ha^{-1} as basal dose + 1 % urea spray at flowering stage. Highest grain yield of cluster bean (10.82 q ha^{-1}) was recorded with 10 kg N ha^{-1} as basal dose + 1 % urea spray at vegetative and flowering stage. Lowest (7.74 q ha^{-1}) grain yield was recorded in the control. Top dressing of 20 kg N ha^{-1} between vegetative and flowering stage and 1 % urea spray at vegetative and flowering stage were at par but with highest gum content (33.60 %). Treatments, 20 kg ha^{-1} as basal dose and split application of N, 10 kg ha^{-1} as a basal dose and 10 kg ha^{-1} as top dressing at first irrigation recorded at par and highest crude protein (29.97 %).

Key words : Cluster bean, pods, seeds, plant, pod length, grain yield, gum content, crude protein

Cluster bean commonly known as guar (*Cyamops tetragonoloba* L.) is an important legume cash crop suitable for the area of low fertility soils, low rain fall and limited irrigation facilities, especially in arid and semi arid regions of India (Kumar *et al.* (2014). The cluster been is tall and bushy annual legume mostly grown on sandy soils of arid and semi arid regions of India, Pakistan and United States (Undersander *et al.* 2006). Cluster bean being a legume crop may help in improving the soil fertility. This legume crop is grown during Kharif season in northwestern states of India such as Rajasthan, Haryana, and Gujarat. This crop is used for gum production and as feed for the cattle. The endosperm of guar seed accounts for about one third of the bean weight and contains the majority of wonderful galactomannan (gum). Approximately 90% of total guar produce is used for production of commercial guar gum and rest is used for culinary purposes and cattle feed etc. Guar gum is used in a number of industrial applications such as oil well drilling, paper, explosives, mining etc. Highly refined guar gum is used as a stiffener in foods like ice cream, stabilizer for cheese, instant puddings and whipped cream substitutes. Churi and Korma are bi-products of gum industries and contain about 35% of protein that can be used as cattle feed. India alone contributes more than 80% of global guar production followed by 15% in Pakistan. The deficient soils require nitrogen as starter dose for leguminous crop (Osborne and Riedell, 2006). Nitrogen not only improves the yield and yield components of legumes (Baboo and Mishra, 2001; Marton and Kadar, 1998) but also affects the biological nitrogen fixation (Akter *et al*. 1998). Therefore, selection of optimum nitrogen rates is essential for better performance of both crop and inoculated rhizobia.

The field experiment was conducted to study the effect of mode and time of nitrogen application on quality, yield and yield attributes in cluster bean (*Cyamops tetragonoloba* L.) at the Forage Research farm of Chaudhary Charan Singh Haryana Agricultural University, Hisar during Khaif 2012. Cluster bean var. HG-563 was taken as test crop. The soil of the experimental field was sandy loam in texture and low in available nitrogen. Four representative soil samples were drawn from different places in the experimental field from 0-15 cm depth before sowing of experimental crop. Composite samples, prepared by passing through 2 mm mesh sieve, were analyzed. In all, 11 treatments were kept for study comprising of different mode and time of nitrogen application and the detail of treatments are given in Table 1. Gross Plot size was 4.5 x 4 m and net size was 3.5 x 3 m. Experiment was laid out in RBD design by keeping three replications. Nitrogen was applied through urea as per the treatments. All the field operations such as hoeing, irrigation *etc* were done as and when required. Crop was harvested at maturity. The grain samples were first dried in the sun for several days and then transferred in an electric hot air oven for drying at a temperature of 70 ± 5^0C till constant weight was achieved. After drying, the grain yield was weighed in kg/plot and then converted in to qha^{-1}, pods per plant, seeds per pod, 100 seeds weight, gum percentage and crude were determined as per standard procedure.

Pods per plant

Data (Table 2) indicated that application of nitrogen @ 20 kg ha^{-1} as a basal significantly increased the number of pods per plant from 45.32 to 48.13 over absolute control. Split application of N, 10 kg ha^{-1} as basal dose and 10 kg ha^{-1} as top dressing at first irrigation further increased the pods number to 52.80. Deshmukh *et al.* (2014) also reported increase in number of pods per cluster with the application of RDF. Balbhim *et al.* (2015) reported increased number of pods per plant with the application of RDF. Highest (53.18) number of pods per plant were observed with 1 % urea spray at vegetative and flowering stage. Increase in pods per plant may be due to the fact that in case of spray of urea, nitrogen is directly absorbed by the plant which gives instant nitrogen supply to the plant. Data further revealed that differences between split application of N and two spray of 1% urea at vegetative and flowering stage was non significant. Lowest pods per plant were recorded in control. Basal dose of 20 kg N ha^{-1} recorded the lowest (48.13) pods per plant except control (45.32).

Seeds per pod

Ten kg N/ha as basal dose+1% urea spray at flowering recorded the highest number of seeds per pod (9.03) (Table 2). Differences between 1% urea at flowering stage, or vegetative and flowering stage, 10 kg N/ha (basal dose)+spray of 1% urea spray at vegetative stage, 10 kg N/ha (basal dose)+spray of 1% urea at flowering stage, and 10 kg N ha^{-1} (basal dose)+spray of 1% urea at vegetative and flowering stage were non significant with respect to seeds per plant. The lowest number of seed per pod (7.73) was observed in the control. Deshmukh *et al*. (2014) also reported increase in number of pods per cluster with the application of RDF.

Pod length

Application of nitrogen @ 1% urea spray at vegetative and flowering stage significantly increased the pod length of cluster bean and increase was 13 % over control (Table 2). However, differences between all these treatments were non significant with respect to the pod length of cluster bean except control (5.35). Deshmukh *et al.* (2014) also reported increase in pod length of cluster bean with the application of RDF.

Table 1. Treatments as per detail given below

Treatments	
T_1	Control (no fertilizers)
T_2	20 kg N ha^{-1}(basal dose)
T_3	10 kg N ha^{-1}(basal dose)+20 kg N ha^{-1} at first irrigation
T_4	20 kg N ha^{-1}(top dressing) between vegetative to flowering stage
T_5	Spray of 1% urea at vegetative stage
T_6	Spray of 1% urea at flowering stage
T_7	Spray of 1% urea at vegetative and flowering stage
T_8	10 kg N ha^{-1}(basal dose)+Spray of 1% urea at vegetative stage
T_9	10 kg N ha^{-1}(basal dose)+Spray of 1% urea at flowering stage
T_{10}	10 kg N ha^{-1}(basal dose)+Spray of 1% urea at vegetative and flowering stage
T_{11}	Spray of 2 % urea at vegetative stage

Table 2. Effect of time and mode of nitrogen application on quality, yield and yield attributes in cluster bean

Treatments	Yield attributing characters				Grain yield (q/ha)	Gum (%)	Crude protein (%)
	Pods/plant (No.)	Seeds/pod (No.)	Pod length (cm)	100-seed (g)			
T_1	45.32	7.73	5.35	3.02	7.74	27.30	29.73
T_2	48.13	8.01	5.62	3.18	8.57	31.65	29.97
T_3	52.80	7.85	5.84	3.21	8.98	32.28	29.97
T_4	51.52	7.95	6.11	3.28	9.16	33.60	29.75
T_5	50.86	7.90	6.13	3.19	8.98	33.08	29.60
T_6	50.95	9.01	6.23	3.20	9.03	33.08	29.31
T_7	53.18	8.55	6.01	3.25	9.56	33.60	29.75
T_8	51.83	8.89	6.13	3.17	9.47	32.10	28.88
T_9	50.97	9.03	5.99	3.29	9.93	31.63	28.66
T_{10}	51.91	8.90	6.11	3.25	10.82	32.63	28.44
T_{11}	49.88	8.04	6.11	3.17	9.27	32.58	28.22
C. D. at 5%	1.52	0.86	0.62	0.18	1.40	0.50	0.59

100-Seed weight

Results from field experiment on cluster bean indicated that application of 10 kg N ha^{-1} as basal dose + 1 % urea spray at flowering stage recorded the maximum 100 seed weight of 3.29 g (Table 2). As in case of pod length of cluster bean, all these treatments were non significant with respect to the 100 seed weight of cluster bean except control (3.02 g). Balbhim *et al.* (2015) reported the increase in 100 seed weight of cluster bean with the application of RDF.

Grain yield

Data (Table 2) revealed that application of nitrogen significantly increased the grain yield of cluster bean and increase was from 7.74 to 10.82 q ha^{-1} with the application of 10 kg N ha^{-1} as basal dose + 1 % urea spray at vegetative and flowering stage over all other treatments except spray of 1 % urea at vegetative and flowering stage (9.56 q ha^{-1}), 10 kg N ha^{-1}(basal dose) + spray of 1 % urea at vegetative stage (9.47 q ha^{-1}), 10 kg N ha^{-1} (basal dose)+spray of 1 % urea at flowering stage (9.93 q ha^{-1}), and spray of 2 % urea at vegetative stage (9.27 q ha^{-1}). Reddy and Reddy (2011) also reported the increase in seed yield of guar with the application of recommended dose of nitrogen.

Gum content

The gum content of cluster bean varied from 27.30 to 33.60 % (Table 2). Treatments of 20 kg N ha^{-1} top dressing between vegetative and flowering stage and 1% urea spray at vegetative and flowering stage recorded at par and highest gum content (33.60 %) over all treatments. Lowest (27.30 %) gum content of cluster bean was recorded in control.

Crude protein

Data (Table 2) revealed that crude protein in cluster bean varied between 28.22 to 29.97 %. Basal dose of 20 kg Nha^{-1} and split application of N, 10 kg ha^{-1} as basal dose and 10 Kg N ha^{-1} as top dressing at first irrigation recorded the at par and highest crude protein (29.97 %) over all other treatments. Spray of 2 % urea at vegetative stage recorded the lowest (28.22%) crude protein. Data further revealed that application of nitrogen had non-significant effect on crude protein of cluster bean, this may be due to the dilution effect. However, Ayub *et al*. (2010 and 2011) reported increased crude protein in guar with application of nitrogen.

CONCLUSION

Application of nitrogen in general increased the yield and yield attributes in cluster bean. It also increased the 100 seed weight and gum content in cluster bean seed. Spray of 1 % urea at flowering stage performed at par with basal dose of nitrogen application.

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Effect of nutrient sources and weed control measures on weed count, N, P and K uptake in weeds and nutrient uptake by baby corn root

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ABSTRACT

A field experiment was conducted during *kharif* season of 2008 at the Experimental Farm of Division of Agronomy, Indian Agricultural Research Institute, New Delhi. Result revealed that number of weeds, uptake of nutrients by weeds and uptake of nutrients by baby corn roots were unaffected by different sources of nutrients except in case of FYM application either with two hand weeding at 20 & 40 DAS or application of atrazine @ 0.5 kg + pendimethalin @ 0.75 kg/ha as. Usurption of N (14.51 and 32.92), (P (2.67 and 6.97) and k (16.21 and 32.65), respectively by monocot (6.97 and 8.76) and dicot 5.13 kg/ha and 6.34) weeds was significantly higher in in the unweeded control in comparison with remaining treatments.

Key words : Baby corn, nutrient usurption by weeds, NPK uptake by crop.

Maize (*Zea mays* L.) is the third most important cereal crop next to rice and wheat at global level. It is used as food for human and feed for livestock. It is also used for poultry and piggery to provide energy rich food. Recently 'specialty corn' is gaining more importance. The demand of baby corn is increasing day by day with the changing food preferences in Indian life style. Baby corn is gaining popularity as a vegetable being a rich source of phosphorus, iron, vitamin A and C, high fiber concentration and no cholesterol (Kawtra and Sahagal, 2007). Use of organic sources of nutrients provides different micro and macro nutrients in balanced proportion as they are the natural products (Ibeawuchi *et al.*, 2007). Besides this, they improve the soil physical condition for better plant growth and development (Ashoka *et al.*, 2008). Owing to congenial weather condition and wider row spacing maize suffers heavily due to severe weed infestation (Malviya and Singh, 2007). The competitive threshold has been defined as the weed density above which crop yield is reduced beyond an acceptable amount (Oliver, 1988). Weed species, densities and their associated interactions influence maize yield loss. When Johnsongrass (*Sorghum halepense* L.) density increased from 4 to 12 plants 9.8 m^{-1} of row, maize grain yield was reduced from 8.5 to 46.6% (Ghosheh *et al*., 1996). Weeds require or consume greater amounts of nitrogen, phosphorus and potassium than crop. Maize crop is very much sensitive to weed competition between 20 to 40 days after sowing (DAS) (Varshney, 1991). Therefore, in view of the above, the present investigation has been proposed to assess the effect of nutrient sources and weed control measures on weeds, changes in soil fertility and economic returns of baby corn.

A field experiment was conducted during *kharif* season of 2008 at the Experimental Farm of Division of Agronomy, Indian Agricultural Research Institute (IARI), New Delhi. The soil of experimental field was sandy loam in texture, poor in organic carbon, low in available N, medium in available P and K and neutral in reaction with pH 7.6. Crop received 342.8 mm precipitation in 17 rainy days. The experiment was laid out in a factorial randomized block design and replicated thrice with the combination of 4 nutrient sources: 120-26.4-41.7 kg N-P-K/ha through fertilizers, 120 kg N through FYM, 120 kg N through leaf compost and 120 kg N through vermicompost and 4 weed management practices: unweeded control, weed free check, two hand weeding at 20 and 40 days after sowing (DAS) and application of atrazine @ 0.5 kg and pendimethalin @ 0.75 kg/ha tank mixed as pre-emergence (PRE). Baby corn variety 'PEHM 2' was sown on the ridges spaced at 60 cm using 20 kg seed/ha. As per the treatment the uniform dose of 120 kg N/ha was applied in the form of urea, 26.4 kg P/ha through SSP and 41.7 kg K/ha through MOP. The ¼ portion of nitrogen and full amount of P, K were applied as basal. Remaining amount of nitrogen was applied in to two equal splits at knee high and tesseling stages. The composition of weed flora as monocots and dicots in the different treatment at 20, 40 DAS were recorded at two spots randomly using a quadrate of size 0.25m^2. The data on weed population was recorded at different intervals from this area. The dried samples were ground and passed through 0.5 mm mesh sieve used for determination of N, P and K concentration following standard procedures. The N, P and K uptake by plant was calculated by multiplying dry matter of weeds/ha with corresponding values of their concentration and were expressed as kg/ha.

Weed count

The important weeds were observed in maize field are – *Cyperus rotundus, Cynodon dactylon, Commelina benghalensis, Digitaria sanguinalis, Dactyloctenium aegyptium, Echinochloa colona and Eragrostis pilosa* among monocots and *Digera arvensis, Trianthema portulacastrum, Phyllanthus niruri* and *Convolvulus arvensis* among dicots. The number of weeds as influenced by nutrient sources and weed control measures at 30 DAS and 50 DAS are presented in Table 1. The number of monocot and dicot weeds showed no significant difference due to nutrient sources. However, slightly higher numbers of weeds were recorded from the application of N through leaf compost. Weed control measures showed significant variation in the number of monocots and dicot weeds at 30 and 50 DAS. In general number of monocot weeds was higher than the dicot weeds in all the treatments at both the stages. The number of monocot and dicot weeds at both the stages were significantly higher in the unweeded control in comparison with two hand weeding at 20 DAS and 40 DAS or application of atrazine 0.5 kg pendimethalin 0.75 kg/ha. No significant differences were observed in monocot, dicot and total weed counts at 20 and 40 DAS in later two treatments. This was mainly due to continuous weeding at the appearance of new weeds. When frequent weeding was made there was hardly any scope for establishment of weeds and their biomass accumulation (Thimmegowda *et al.*, 2007).

N, P and K uptake in weeds

The data on N, P and K uptake in weeds as influenced by different treatments has been presented in Table 1. No significant differences were recorded in N, P and K uptake in weeds due to nutrient sources at 30 and 50 DAS; however, these values were significantly varied due to different weed control measure at both the stages. Significantly higher N, P and K uptake in weeds was recorded from unweeded control over all other weed control measures while significantly lowest N, P and K uptake in weeds were recorded from weed free check at both stages. Two hand weeding at 20 and 40 DAS recorded statistically similar N, P and K uptake in weeds as observed from the application of atrazine 0.5 kg + pendimethalin 0.75 kg/ha. Unweeded control treatment facilitated higher nitrogen, phosphorus and potassium uptake than the weed free treatment owing to increase in dry matter accumulation in weeds and higher weed infestation (Gulleria and Singh, 1979).

N, P, K, Zn and Fe uptake in baby corn root

Among the nutrient sources, N and P uptake in roots was found significantly higher when N was applied through vermicompost over recommended dose of NPK applied through fertilizers and it was at par with N applied through FYM and N through leaf compost (Table 2). Uptake of K in roots was significantly higher in the treatments where N was applied through vemicompost or FYM in comparison with recommended dose of NPK applied through fertilizers. The maximum Zn and Fe uptake in roots was recorded from the treatment where N was applied through FYM and vermicompost, respectively. Pawar and Patil (2007) observed that uptake of major and micro nutrient in maize were maximum due to combined application of vermicompost and RDF through fertilizers. Among the weed control measure, significantly higher N, P, K, Zn and Fe uptake in root was found with in weed free check treatment over unweeded control.

CONCLUSION

Based on findings of present investigation, it may be concluded that all the nutrient sources had no effect on weed count, nutrient removel by weeds. Weed free check recorded least weeds and nutrient removal, however, highest N, P, K, Zn, and Fe uptake may be obtained with the application of 120 kg N through vermicompost followed by same amount of N through FYM.

Table 1. Effect of nutrient sources and weed control measures on weeds count and N, P and K uptake in weeds

Treatment	30 DAS			50 DAS			30 DAS			50 DAS		
	Weeds/m^2			Weeds/m^2			Uptake (kg/ha)			Uptake (kg/ha)		
	Monocot	Dicot	Total	Monocot	Dicot	Total	N	P	K	N	P	K
Nutrient sources												
120-26.4-41.7 kg N-P-K/ha through fertilizers	4.05 (23.0)	2.99 (10.7)	5.06 (33.7)	5.82 (43.0)	3.71 (16.9)	6.85 (59.9)	6.90	1.27	8.48	18.38	3.59	20.48
N through FYM	3.57 (20.7	2.76 (9.5)	4.86 (29.5)	5.70 (41.3)	3.42 (15.3)	6.68 (56.5)	7.90	1.46	9.18	18.99	4.45	20.07
N through leaf compost	4.19 (23.7)	3.24 (13.3)	5.10 (36.9)	5.84 (43.6)	4.17 (23.6)	7.08 (67.3)	7.64	1.44	8.36	19.21	4.73	20.72
N through vermicompost	3.94 (20.3)	2.90 (10.6)	4.88 (30.9)	5.77 (42.6)	3.61 (16.6)	6.72 (59.3)	7.26	1.32	8.35	20.11	4.60	18.52
S. Em±	0.39	0.15	0.28	0.25	0.21	0.25	0.27	0.07	0.30	0.80	0.47	1.13
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Weed control measures												
Unweeded control	6.97 (54.7)	5.13 (26.0)	8.98 (80.7)	8.76 (76.7)	6.34 (40.9)	10.83 (117.6)	14.51	2.67	16.21	32.92	6.97	32.65
Weed free check	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.00	0.00	0.00	0.00	0.00	0.00
Two hand weeding at 20 & 40 DAS	3.80 (15.7)	2.96 (8.7)	4.84 (24.3)	6.75 (46.0)	3.78 (14.3)	7. 85 (60.3)	7.56	1.46	9.30	21.74	5.41	23.30
Atrazine @ 0.5 kg+pendimethalin @ 0.75 kg/ha as PE	4.29 (19.7)	3.10 (9.7)	5.37 (29.3)	6.92 (48.0)	4.08 (17.3)	7. 96 (65.3)	7.64	1.37	8.87	22.32	4.99	23.85
S. Em±	0.39	0.15	0.28	0.25	0.21	0.25	0.27	0.007	0.30	0.80	0.47	1.13
CD (P=0.05)	1.12	0.44	0.80	0.73	0.61	0.72	0.79	0.020	8.48	2.32	0.13	3.28

*Square-root transformed value$\sqrt{x+0.5}$; Original values are in parenthesis.

Table 2. Effect of nutrient sources and weed control measures on N, P, K, Zn and Fe uptake in baby corn root (0-15cm)

Treatment	Uptake (kg/ha)				
	N	P	K	Zn	Fe
Nutrient sources					
120-26.4-41.7 kg N-P-K/ha through fertilizers	3.40	0.17	22.28	68	1110
N through FYM	4.85	0.27	29.98	117	2190
N through leaf compost	4.60	0.22	28.35	106	1960
N through vermicompost	5.17	0.29	30.03	110	2200
S. Em±	0.49	0.037	2.34	9.1	180
CD (P=0.05)	1.46	0.107	6.76	26	520
Weed control measures					
Unweeded control	3.39	0.16	20.77	60	1310
Weed free check	5.07	0.28	30.48	117	2180
Two hand weeding at 20 & 40 DAS	4.65	0.23	28.56	112	1950
Atrazine @ 0.5 kg+pendimethalin @ 0.75 kg/ha as PE	4.63	0.26	29.53	110	1930
S. Em±	0.49	0.037	2.34	9.1	180
CD (P=0.05)	1.46	0.107	6.76	26	520

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Efficacy of different weed control methods inspring planted maize

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ABSTRACT

A field experiment was conducted at CCS Haryana Agricultural University, Regional Research Station, Karnal during *Spring* 2013. Twelve treatments of different herbicides and their combinations using pendimethalin 1.0 and 1.5 kg ha^{-1}(Pre-emergence) PRE, atrazine 0.50 and 0.75 kg ha^{-1}PRE and (Post-emergence) POE (15 DAS), metribuzin 140 and 210 g ha^{-1} PRE, tank mix PRE application of metribuzin 70 g ha^{-1} + atrazine 0.25 kg ha^{-1} and pendimethalin 0.75 kg ha^{-1} + atrazine 0.25 kg ha^{-1}, atrazine 0.50 kg ha^{-1} PRE *fb* 2,4-D Na salt 0.50 kg ha^{-1} at 40 DAS and hoeing at 20 DAS *fb* atrazine 0.50 kg ha^{-1} PRE were compared with two hand weeding (HW) 20 and 40 DAS, weedy check and weed free treatment. All the fifteen treatments were arranged in a Random Block Design (RBD) with three replications. Experimental field was dominated by grassy and broad-leaf weeds with small infestation of sedges. Results revealed that hoeing at 20 DAS *fb* atrazine 0.50 kg ha^{-1}(PRE to weeds) recorded significantly lower weed population at all the growth stages. Highest weed control efficiency (WCE) was recorded in metribuzin 210 g ha^{-1} PRE, followed by atrazine 0.50 kg ha^{-1} PRE *fb* 2, 4-D Na salt 0.5 kg ha^{-1} at 40 DAS and minimum with atrazine 0.50 kg ha^{-1} POE at 15 DAS.

Key words : *Zea mays*, herbicides, weed control efficiency, grain yield, fodder yield, economics

INTRODUCTION

Maize (*Zea mays L.*) or corn or makki belonging to *Poaceae* family is one of the major cereal crop with wide adaptability to diverse agro-climatic conditions around the world. It isgrown over an area of 159 mha with a total production of 819 mt. Maize is cultivated throughout the year in all the states of India for various purposes including grain, fodder, green cobs, sweet corn, baby corn and popcorn in semi-urban areas. Predominantly maize is grown as rain fed crop and its productivity is much more than rice which is mainly grown under assured irrigation conditions.

Maize production suffers greatly due to weeds, which offers multifarious limitations in production. It was found that due to continuous and heavy rains during the entire vegetative and early reproductive stages of maize growth, weeds infestation becomes unmanageable using the traditional method of inter-culturing and manual weeding. Though these methods are effective in controlling weeds during normal to low rainfall areas, they are tedious and time consuming besides labour intensive,costly and provide lower weed control efficiency (WCE). However, with the introduction of herbicides, weed management has become timely, efficient, easy application that saves time and is more economical. This is particularly true under intensive crop production practices with high yielding varieties that demand greater amount of fertilizer and water, which are also conducive to greater weed growth.The choice of any weed control measures therefore, depends largely on its effectiveness and economics. Because of increased cost and non-availability of manual labour in the required quantity for hand weeding, herbicides not only control the weeds timely and effectively, but also offer a great scope for minimizing the cost of weed control irrespective of the situation. Use of pre-emergence (PRE) and post-emergence (POE) herbicides would make the herbicidal weed control more acceptable to farmers, which will not change the existing agronomic practices, but will allow for complete control of weeds and no/ minimal crop injury/suppression. Usage of PRE herbicides assumes greater significance in view of their effectiveness from initial stages. As the weeds interfere during the later growth stages and also in harvesting of the crop, POE herbicides at about 30-40 DAS may help in avoiding the problem of weeds at later stages. Under the prevailing situation, managing weeds through PRE and POE herbicides or integrated with normal weeding will be an ideal method for controlling weeds in view of their economics and effectiveness in maize.

Efficacy of different herbicides may also vary with different planting methods in any crop including maize. Therefore, there is need to find out promising herbicide combinations to manage weeds in spring planted maize. Keeping these points in views, the present investigation was planned with the objective of efficacy of different weed control methods on weed control efficiency in *spring* planted maize.

MATERIALS AND METHODS

A field experiment on the efficacy of different weed control methods on weed control efficiency in *spring* planted maize was conducted at Regional Research Station Karnal, CCS, Haryana Agricultural University, Hisar, Haryana during *spring* 2013. Twelve treatments of different herbicides and their combinations comprising of pendimethalin 1.0 and 1.5 kg ha^{-1}PRE, atrazine 0.50 and 0.75 kg ha^{-1}PRE and POE (15 DAS), metribuzin 140 and 210 g ha^{-1} applied PRE, tank mix PRE application of metribuzin 70 g ha^{-1} + atrazine 0.25 kg ha^{-1} and pendimethalin 0.75 kg ha^{-1} + atrazine 0.25 kg ha^{-1}, atrazine 0.50 kg ha^{-1} PRE *fb* 2,4-D Na salt 0.50 kg ha^{-1} at 40 DAS and hoeing at 20 DAS *fb* atrazine 0.50 kg ha^{-1} PRE were compared with two hand weeding (HW) 20 and 40 DAS, weedy check and weed free treatment. All the fifteen treatments were arranged in a Random Block Design (RBD) with three replications. Full dose of phosphorus (60 kg ha^{-1}) and potassium (60 kg ha^{-1}) and 1/4th dose of nitrogen (37.5kg ha^{-1}) through DAP, MOP and Urea, respectively were applied as a basal dose at the time of sowing and remaining 3/4th dose of nitrogen (112.5 kg ha^{-1}) was top dressed through Urea in 3 equal splits *i.e.* at knee high stage, tasseling stage and dough stage. Hybrid maize CV. HQPM 1 was planted on 06 March 2013 using 20 kg seed/ha at row-row spacing of 60 cm and plant–plant spacing of 20 cm. Seed was treated with carbendazim 2 g kg^{-1} seed just before sowing to ensure crop protection from soil and seed borne diseases. The crop was sprayed with Carbaryl (Sevin) 2 g litre^{-1} of water 30 days after sowing (DAS) to control shoot fly with Knapsack sprayer**.** Crop was raised as per Package of Practices of CCS HAU Hisar and was harvested on 31 June 2013. Herbicides were sprayed using backpack sprayer fitted with flood-jet nozzles delivering 500 L/ha water. Data of weed population was recorded 30, 60, 90 DAS and at harvest for grassy, broadleaf weeds and sedges. Weed control efficiency at 30, 60, 90 DAS and crop maturity, was calculated by using the following formula and expressed in percentage :

$$\text{WCE (\%)} = \frac{\text{Dry weight of weeds in control} - \text{Dry weight of weeds in treatment}}{\text{Dry weight of weeds in control}} \times 100$$

Population data individual or total weeds was subjected to angular transformation before analysis. Similarly weed control efficacy data was arcsine transformed and subject to ANOVA. Means were separated using LSD method for comparisons.

RESULTS AND DISCUSSION

Density of grassy weeds

The major weed flora infesting the field was *Dactyloctenium aegyptium, Brachiaria sp., Trianthema portulacastrum, Digera arvensis, Echinochloa colona* and *Euphorbia microphylla*.

All weed control treatments significantly influenced grassy weeds density compared to weedy check at all the crop growth stages (Table 1). Increasing the rates of PRE herbicides (pendimethalin, atrazine and metribuzin) by 50% resulted in significantly greater reduction in grassy weeds density 30 DAS and was comparable to hand weeding 20 DAS, compared to their lower rates. Metribuzin 210 g/ha or pendimethalin 1.5 kg/ha PRE was more effective than atrazine 0.75 kg/ha applied PRE or 15 DAS or the tank mix application of metribuzin 70 g ha^{-1} + atrazine 0.25 kg ha^{-1} PRE or pendimethalin 0.75 kg ha^{-1} + atrazine 0.25 kg ha^{-1} PRE on grassy weeds density 30 DAS. Though minimum grassy weeds density was recorded in HW 20 DAS *fb* atrazine 0.50 kg/ha. Density of grassy weeds increased gradually upto 60 DAS and then decreased at 90 DAS and at harvest.

Density of broad-leaved weeds

In different weed control treatments density of broad-leaf weeds was highest in weedy check and lowest

Table 1. Effect of different treatments on density of grassy weeds

Treatments	Density of weeds (No. m^{-2})			
	30 DAS	60 DAS	90 DAS	At harvest
Pendimethalin 1.0 kg ha^{-1} PRE	3.4 (11.1)	4.8 (23)	4.5 (19.3)	4.1 (16.3)
Pendimethalin 1.5 kg ha^{-1} PRE	2.7 (6.8)	4.2 (17.3)	3.8 (13.6)	3.3 (10.3)
Atrazine 0.50 kg ha^{-1} PRE	4.7 (21.3)	5.8 (33)	5.3 (27.6)	4.9 (24.0)
Atrazine 0.75 kg ha^{-1} PRE	4.5 (19.6)	5.4 (28.3)	5.0 (24.6)	4.7 (22.0)
Atrazine 0.50 kg ha^{-1} POE at 15 DAS	4.8 (23.0)	6.2 (37.6)	5.9 (34.0)	5.5 (29.6)
Atrazine 0.75 kg ha^{-1} POE at 15 DAS	4.6 (20.3)	5.7 (32.3)	5.4 (28.6)	5.2 (26.3)
Metribuzin 140 g ha^{-1} PRE	3.5 (11.6)	4.5 (19.3)	4.0 (15.6)	3.9 (14.6)
Metribuzin 210 g ha^{-1} PRE	2.7 (6.5)	3.9 (15)	3.4 (11.3)	3.1 (9.0)
Metribuzin 70 g ha^{-1} + atrazine 0.25 kg ha^{-1} PRE	3.8 (13.6)	4.4 (18.6)	3.9 (15.0)	3.5 (12.3)
Pendimethalin 0.75 kg ha^{-1} + atrazine 0.25 kg ha^{-1} PRE	3.6 (12.6)	6.1 (37.3)	5.8 (33.6)	5.5 (29.6)
Atrazine 0.50 kg ha^{-1} PRE *fb* 2, 4-D Na salt 0.5 kg ha^{-1} at 40 DAS	4.6 (20.6)	5.4 (29.3)	5.0 (25)	4.8 (23.3)
Hoeing at 20 DAS *fb* atrazine 0.50 kg ha^{-1} (PRE to weeds)	2.3 (4.3)	5.1 (26.0)	4.7 (22.0)	4.5 (19.6)
Two hand hoeing (20 and 40 DAS)	2.5 (5.8)	3.9 (14.3)	4.2 (17.0)	4.0 (15.3)
Weedy check	5.1 (25.1)	7.5 (56.3)	6.6 (43.6)	6.3 (39.6)
Weed free	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)
C.D at 5%	0.6	0.5	0.7	0.7

Original data in parenthesis subjected to square root $\sqrt{(x+1)}$ transformation.

Table 2. Effect of different treatments on density of broad-leaved weeds

Treatments	Density of weeds (No. m^{-2})			
	30 DAS	60 DAS	90 DAS	At harvest
Pendimethalin 1.0 kg ha^{-1} PRE	2.8 (7.2)	3.3 (10.0)	2.2 (4.0)	1.4 (1.3)
Pendimethalin 1.5 kg ha^{-1} PRE	2.5 (5.3)	2.8 (7.0)	2.0 (3.2)	1.4 (1.1)
Atrazine 0.50 kg ha^{-1} PRE	2.2 (3.8)	2.4 (5.1)	1.8 (2.7)	1.3 (0.7)
Atrazine 0.75 kg ha^{-1} PRE	2.1 (3.5)	2.1 (3.8)	1.7 (2.2)	1.2 (0.4)
Atrazine 0.50 kg ha^{-1} POE at 15 DAS	2.3 (4.6)	2.6 (6.1)	2.0 (3.1)	1.2 (0.6)
Atrazine 0.75 kg ha^{-1} POE at 15 DAS	1.9 (3.0)	2.2 (4.3)	1.8 (2.6)	1.2 (0.4)
Metribuzin 140 g ha^{-1} PRE	2.2 (3.8)	2.4 (5.1)	1.9 (2.7)	1.2 (0.6)
Metribuzin 210 g ha^{-1} PRE	1.9 (2.6)	2.1(3.5)	1.8 (2.4)	1.2 (0.5)
Metribuzin 70 g ha^{-1}+ atrazine 0.25 kg ha^{-1}PRE	1.9 (3.0)	2.3(4.6)	1.9 (2.7)	1.3 (0.8)
Pendimethalin 0.75 kg ha^{-1} + atrazine 0.25 kg ha^{-1} PRE	2.4 (5.1)	2.5 (5.5)	2.1 (3.6)	1.3 (1.1)
Atrazine 0.50 kg ha^{-1}PRE *fb* 2, 4-D Na salt 0.5 kg ha^{-1} at 40 DAS	1.6 (1.7)	1.8 (2.7)	1.5 (1.4)	1.1 (0.3)
Hoeing at 20 DAS *fb* atrazine 0.50 kg ha^{-1} (PRE to weeds)	1.6 (1.6)	2.0 (3.1)	1.4 (1.2)	1.2 (0.4)
Two hand hoeing (20 and 40 DAS)	1.5 (1.3)	1.7 (2.0)	1.4 (1.0)	1.1 (0.2)
Weedy check	4.3 (17.7)	4.5 (19.4)	3.2 (9.8)	1.8 (2.5)
Weed free	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)
SE(m)	0.1	0.1	0.1	0.1
C.D at 5%	0.3	0.4	0.3	0.3

Original data in parenthesis subjected to square root $\sqrt{(x+1)}$ transformation.

in weed free followed by two HW (20 and 40 DAS), at all the stages (Table 2). In herbicidal treatments, density of broad-leaf weeds was lowest in atrazine 0.50 kg ha^{-1} PRE *fb* 2,4-D Na salt 0.5 kg ha^{-1} at 40 DAS, which was at par with hoeing at 20 DAS *fb* atrazine 0.50kg ha^{-1}. Higher dose of pendimethalin (1.5 kg ha^{-1}) significantly reduced the density of broadleaf weeds compared to its lower dose (1.0 kg ha^{-1}) which proved inferior among all herbicidal treatments at 30 and 60 DAS. Later on, both the doses of pendimethalin were at par in reducing the density of broadleaf weeds. Increased dose of atrazine from 0.50 to 0.75 kg ha^{-1}applied either PRE or POE did not influence the density of broadleaf weeds. Hoeing at 20 DAS *fb* atrazine at 0.50 kg $ha^{-1}$and atrazine at 0.50 kg ha^{-1}PRE *fb* application of 2,4-D Na salt (0.50kg ha^{-1}) at 40 DAS was superior to the alone application of atrazine (0.50 kg/ha) PRE or POE and pendimethalin 1.0 kg ha^{-1} PRE at 30, 60 and 90 DAS. Application of metribuzin 210 g ha^{-1} PRE being at par with atrazine applied PRE or POE significantly reduced the density of broadleaf weeds compared to the pendimethalin 1.0 kg ha^{-1} PRE.

Density of sedges

Density of sedges increased gradually upto 60 DAS and then decreased at 90 DAS and at harvest in weed free followed by two HW (20 and 40 DAS) and was highest in weedy check at all the growth stages (Table 3). The density of sedges was significantly lower in hoeing at 20 DAS *fb* atrazine 0.50 kg ha^{-1}at 30 and 60 DAS compared to other herbicide treatments. At 90 DAS and at harvest, lowest density of sedges was found in metribuzin 210 g ha^{-1} PRE. Higher dose of pendimethalin PRE, atrazine PRE or POE had similar density of sedges compared to their lower doses. However, increase in dose of metribuzin from 140 g ha^{-1} to 210 g ha^{-1} significantly reduced the density of sedges at 30 and 90 DAS. Density of sedges was almost similar in plots treated with atrazine (0.50 kg ha^{-1} PRE), and in plots treated with tank mix of pendimethalin 0.75 kg ha^{-1} + atrazine 0.25kg ha^{-1}.

Density of total weeds

Different weed control treatments significantly influenced total density of weeds; it was lowest in weed free followed by two HW (20 and 40 DAS) and highest in weedy check at all the stages (Table 4). In herbicidal treatments, density of total weeds was lowest in metribuzin 210 g ha^{-1} PRE, followed by pendimethalin 1.5 kg ha^{-1} PRE at all the stages. Higher dose of pendimethalin (1.5 kg ha^{-1}) and atrazine (0.75 kg ha^{-1}) did not significantly reduce the density of total weeds compared to its lower dose (1.0 kg ha^{-1}) at all the stages. However, higher dose of metribuzin (210 g ha^{-1}) significantly reduced the density of total weeds compared to its lower dose (140 g ha^{-1}). Treatment of hoeing at 20 DAS *fb* atrazine at 0.50 kg ha^{-1} and atrazine at 0.50 kg ha^{-1} PRE *fb* application of 2,4-D Na salt (0.50 kg ha^{-1}) at 40 DAS was superior over alone application of atrazine (0.50 kg ha^{-1}) PRE or POE and pendimethalin 1.0 kg ha^{-1}PRE at 30, 60 and 90 DAS. Alone application of pendimethalin (1.5 kg ha^{-1}) or atrazine (0.75 kg ha^{-1}) proved significantly superior to the

Table 3. Effect of different treatments on density of sedge

Treatments	Density of weeds (No. m^{-2})			
	30 DAS	60 DAS	90 DAS	At harvest
Pendimethalin 1.0 kg ha^{-1} PRE	4.3 (18.0)	5.1 (26.0)	4.4 (19.0)	3.8 (13.6)
Pendimethalin 1.5 kg ha^{-1} PRE	3.9 (15.0)	5.5 (29.6)	4.9 (23.3)	4.2 (17.3)
Atrazine 0.50 kg ha^{-1} PRE	3.9 (14.3)	4.8 (22.6)	4.4 (18.6)	3.9 (14.3)
Atrazine 0.75 kg ha^{-1} PRE	3.5 (12.0)	4.4 (19.0)	3.9 (15.0)	3.5 (11.3)
Atrazine 0.50 kg ha^{-1} POE at 15 DAS	4.3 (18.3)	5.2 (27.3)	4.7 (22.0)	4.3 (18.0)
Atrazine 0.75 kg ha^{-1} POE at 15 DAS	4.0 (15.6)	4.8 (23.0)	5.3 (28.0)	4.6 (20.3)
Metribuzin 140 g ha^{-1} PRE	3.9 (14.6)	4.6 (21.0)	3.6 (12.6)	3.3 (10.3)
Metribuzin 210 g ha^{-1} PRE	3.2 (9.3)	4.3 (18.3)	3.1 (9.0)	2.9 (7.6)
Metribuzin 70 g ha^{-1}+ atrazine 0.25 kg ha^{-1}PRE	3.5 (12.0)	4.7 (22.0)	4.1 (16.3)	3.5 (11.6)
Pendimethalin 0.75 kg ha^{-1} + atrazine 0.25 kg ha^{-1} PRE	4.1 (16.0)	5.0 (24.6)	4.6 (21.0)	4.0 (15.6)
Atrazine 0.50 kg ha^{-1}PRE *fb* 2, 4-D Na salt 0.5 kg ha^{-1} at 40 DAS	3.4 (11.0)	4.6 (20.6)	4.3 (17.6)	3.3 (10.3)
Hoeing at 20 DAS *fb* atrazine 0.50 kg ha^{-1} (PRE to weeds)	2.2 (4.0)	4.2 (17.3)	3.9 (14.6)	3.4 (11.0)
Two hand hoeing (20 and 40 DAS)	2.0 (3.3)	4.1 (16.1)	3.1 (9.0)	2.9 (7.6)
Weedy check	4.5 (19.3)	5.4 (29.0)	5.1 (25.3)	4.3 (18.0)
Weed free	1.0 (0.0)	1.0 (0.0)	1.0(0.0)	1.0(0.0)
SE(m)	0.2	0.2	0.1	0.1
C.D at 5%	0.5	0.7	0.4	0.4

Original data in parenthesis subjected to square root $\sqrt{(x+1)}$ transformation.

Table 4. Effect of different treatments on total density of weeds

Treatments	Density of weeds (No. m^{-2})			
	30 DAS	60 DAS	90 DAS	At harvest
Pendimethalin 1.0 kg ha^{-1} PRE	6.1 (36.3)	7.7 (59.0)	6.5 (42.3)	5.6 (31.3)
Pendimethalin 1.5 kg ha^{-1} PRE	5.3 (27.1)	7.4 (54.0)	6.4 (40.2)	5.4 (28.7)
Atrazine 0.50 kg ha^{-1} PRE	6.3 (39.5)	7.8 (60.7)	7.0 (49.1)	6.3 (39.1)
Atrazine 0.75 kg ha^{-1} PRE	6.0 (35.3)	7.2 (51.2)	6.5 (41.8)	5.8 (33.7)
Atrazine 0.50 kg ha^{-1} POE at 15 DAS	6.8 (46.0)	8.4 (71.1)	7.7 (59.1)	7.0 (48.3)
Atrazine 0.75 kg ha^{-1} POE at 15 DAS	6.3 (39.0)	7.7 (59.6)	7.7 (59.3)	6.9 (47.1)
Metribuzin 140 g ha^{-1} PRE	5.5 (30.2)	6.8 (45.4)	5.6 (31.1)	5.1 (25.6)
Metribuzin 210 g ha^{-1} PRE	4.4 (18.5)	6.1 (36.8)	4.8 (22.7)	4.2 (17.2)
Metribuzin 70 g ha^{-1}+ atrazine 0.25 kg ha^{-1}PRE	5.4 (28.6)	6.8 (45.3)	5.9 (34.1)	5.0 (24.8)
Pendimethalin 0.75 kg ha^{-1} + atrazine 0.25 kg ha^{-1} PRE	5.8 (33.7)	8.2 (67.5)	7.6 (58.3)	6.8 (46.4)
Atrazine 0.50 kg ha^{-1}PRE *fb* 2, 4-D Na salt 0.5 kg ha^{-1} at 40 DAS	5.8 (33.4)	7.3 (52.7)	6.7 (44.4)	6.0 (35.6)
Hoeing at 20 DAS *fb* atrazine 0.50 kg ha^{-1} (PRE to weeds)	3.5 (11.5)	6.8 (46.4)	6.2 (37.8)	5.6 (31.1)
Two hand hoeing (20 and 40 DAS)	3.1 (8.9)	5.7 (32.6)	5.2 (27.0)	4.9 (23.2)
Weedy check	7.9 (62.2)	10.2 (104.7)	8.9 (78.8)	7.8 (60.2)
Weed free	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)
SE(m)	0.1	0.2	0.2	0.2
C.D at 5%	0.5	0.6	0.6	0.6

Original data in parenthesis subjected to square root $\sqrt{(x+1)}$ transformation.

treatment of tank mix of pendimethalin 0.75 kg ha^{-1}+ atrazine 0.25 kg ha^{-1} PRE.

Weed control efficiency oftotal weeds

The data indicated that weed free attained highest WCE followed by two HW (20 and 40 DAS), at all the stages whereas, it was lowest in weedy check (Table 5). In herbicidal treatments, higher WCE was recorded in metribuzin 210 g ha^{-1} PRE, followed by atrazine 0.50 kg ha^{-1} PRE *fb* 2, 4-D Na salt 0.5 kg ha^{-1} at all stages except 60 DAS, which was at par with all treatments except pendimethalin 1.0 kg ha^{-1} PRE and metribuzin 140 g ha^{-1} PRE. Hoeing at 20 DAS *fb* atrazine 0.50 kg ha^{-1} being at par with two HW (20 and 40 DAS), registered significantly higher WCE compared to alone application of atrazine PRE, 0.50 kg ha^{-1} PRE *fb* 2,4-D Na salt 0.50 kg ha^{-1} applied 40 DAS at all growth stages.

The results revealed that density of weeds was higher in atrazine 0.50 kg ha^{-1} POE at 15-20 DAS and lowest in hoeing at 20 DAS followed by atrazine 0.50 kg ha^{-1}. Dry matter of weeds was higher in atrazine 0.50 kg ha^{-1} POE at 15-20 DAS and lowest in hoeing at 20 DAS followed by atrazine 0.50 kg ha^{-1} at all stages except 30 DAS in pendimethalin 1.0 kg ha^{-1} PRE. Highest weed control efficiency was recorded in hoeing at 20 DAS followed by atrazine 0.50 kg/ha and lowest in atrazine 0.50 kg ha^{-1} POE at 15-20 DAS.

Reduction in yield to the extent of 32.4 to 42.3% due to weed growth has been reported in maize (Sharma and Gautam, 2006). Most of the presently available herbicides (atrazine or pendimethalin) provide only narrow spectrum weed control in maize, and therefore, effective and economical method for weed control in maize using new herbicides is required. Prasad and Mani (1986) reported reduction in grain yield by 80.45 % in un-weeded check as compared to highest (6065 kg ha^{-1}) yield attained through PRE application of atrazine (1.25 kg ha^{-1}) followed by (*fb*) earthing-up (20 DAS). They also observed that atrazine PRE was highly economical (additional cost Rs 5706 ha^{-1}) as compared to manual weeding. Kolage *et al.* (2003) reported that among the herbicides, atrazine 1.0 kg ha^{-1} PRE reduced weed intensity substantially and recorded lower weed index (WI) and maximum WCE as compared to other herbicides. Subhendu *et al.* (2004) found that atrazine 1.0 kg ha^{-1} PRE + one HW 30 DAS recorded higher number of cobs per plant, weight of cob with husk and without husk and followed by two HW at 20 and 40 DAS. Utpal and Bandhopadhyay (2009) found highest values of growth attributes, yield component, grain yield, and length of cob under PRE application of metribuzin 600 g ha^{-1}, and minimum number and dry weight of total weeds recorded under HW twice at 20 and 40 DAS. However, the highest

Table 5. Effect of different treatments on weed control efficiency of weeds

Treatments	Density of weeds (No. m^{-2})			
	30 DAS	60 DAS	90 DAS	At harvest
Pendimethalin 1.0 kg ha^{-1} PRE	56.4 (69.5)	52.9 (63.8)	49.9 (58.5)	38.1 (38.4)
Pendimethalin 1.5 kg ha^{-1} PRE	59.6 (74.5)	56.0 (68.8)	53.2 (64.2)	46.0 (51.8)
Atrazine 0.50 kg ha^{-1} PRE	57.9 (71.5)	53.3 (64.4)	50.8 (60.0)	40.9 (43.1)
Atrazine 0.75 kg ha^{-1} PRE	61.0 (76.5)	55.6 (68.2)	52.6 (63.1)	38.3 (38.6)
Atrazine 0.50 kg ha^{-1} POE at 15 DAS	54.9 (66.8)	52.8 (63.5)	49.7 (58.3)	38.4 (38.7)
Atrazine 0.75 kg ha^{-1} POE at 15 DAS	57.2 (70.7)	53.7 (64.9)	51.6 (61.5)	41.7 (44.6)
Metribuzin 140 g ha^{-1} PRE	60.2 (75.3)	55.8 (68.4)	53.9 (65.3)	43.2 (47.2)
Metribuzin 210 g ha^{-1} PRE	61.9 (77.7)	57.5 (71.1)	55.9 (68.5)	48.0 (55.1)
Metribuzin 70 g ha^{-1}+ atrazine 0.25 kg ha^{-1}PRE	57.0 (70.1)	53.0 (63.9)	49.9 (58.5)	40.1 (41.6)
Pendimethalin 0.75 kg ha^{-1} + atrazine 0.25 kg ha^{-1} PRE	58.6 (72.7)	54.6 (66.4)	51.0 (60.5)	41.3 (43.6)
Atrazine 0.50 kg ha^{-1}PRE *fb* 2, 4-D Na salt 0.5 kg ha^{-1} at 40 DAS	60.0 (74.9)	55.9 (68.6)	53.9 (65.2)	44.9 (50.0)
Hoeing at 20 DAS *fb* atrazine 0.50 kg ha^{-1} (PRE to weeds)	67.7 (85.9)	59.2 (73.9)	58.3 (72.3)	51.9 (62.6)
Two hand hoeing (20 and 40 DAS)	69.3 (87.5)	61.2 (76.8)	60.4 (75)	57.2 (70.0)
Weedy check	0.0	0.0	0.0	0.0
Weed free	90.0 (100)	90.0 (100)	90.0 (100)	90.0 (100)
SE(m)	1.9	0.8	1.4	2.9
C.D at 5%	5.7	2.4	4.2	8.5

Original data in parenthesis subjected to angular transformation.

WCE was recorded under metribuzin 600 g ha^{-1} PRE over un-weeded control. Patel *et al*. (2006) reported maximum WCE (98%) with atrazine at 0.5 kg ha^{-1} PRE in conjunction with pendimethalin 0.25 kg ha^{-1} closely followed by atrazine + alachlor each applied at 0.5 kg ha^{-1}. Similar trend was observed in grain and stover yield, net return and cost: benefit. Among weed control methods, atrazine 1.5 kg ha^{-1} being statistically at par with acetachlor 1.25 kg ha^{-1} produced significantly lower density and dry matter of weeds and resulted in significant increase in all the yield attributes of maize crop and thereby it increased grain yield by 75.18 and 71.66%, respectively, over un-weeded check.

CONCLUSION

Results revealed that hoeing at 20 DAS *fb* atrazine 0.50 kg ha^{-1}(PRE to weeds) recorded significantly lower weed population at all growth stages. In herbicidal treatments highest weed control efficiency (WCE) was recorded in metribuzin 210 g ha^{-1} PRE, followed by atrazine 0.50 kg ha^{-1} PRE *fb* 2, 4-D Na salt 0.5 kg ha^{-1} at all stages and minimum with atrazine 0.50 kg ha^{-1} POE at 15 DAS.

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Resurgence of rice leaf folder *Cnaphalocrocis medinalis* Guenee due to application of phorate granules

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ABSTRACT

Studies on the resurgence of *Cnaphalocrocis medinalis* after the repeated application of phorate 10G was carried out on variety HKR 120. Higher leaf damage and pest incidence was observed in the plots, where repeated applications of the phorate 10G were made indicating the resurgence of the pest. Best leaf protection was achieved with foliar application of monocrotophos 36SL @ 0.2 Kg a.i./ha. Three applications of phorate @ 0.5 and 1.0 kg a.i./ha resulted in net loss of Rs. 686.00 and Rs. 1840.00/ha, respectively due to increase in cost of spray.

Key words : Pest incidence, rice, foliar application, leaf folder

INTRODUCTION

Rice, *Oryza sativa* (L.) is one of the most important cereal crop cultivated throughout the world. Insect pests and diseases are the major constraint threatening grain yield of this crop all over the rice growing countries of the world. Attainable yield losses of 51.4% have been reported worldwide accounting 20.7% due to animal pests including insect pests, 15.6% due to weeds and 15.1% due to pathogens resulting into monetary loss amounted to $113 billion (Oerke, 1994). Out of 100 spp. of insects known to attack the rice crop, white backed plant hopper, stem borers, leaf folder and root weevil have assumed serious form in Haryana (Kushwaha, 1988a). Among these rice leaf folder, *Cnaphalocrocis medinalis* (Guenee) (Lepidoptera : Pyralidae) is a predominant foliage feeder and one of the most destructive pests, affecting all the rice ecosystem in Asia (Luo, 2010). With the serious outbreak during drought season in 1987 (Kushwaha, 1988b), the pest has now established as a regular major pest of rice in Haryana. Yield reduction of 30-80% has been reported due to this pest under epidemic situation (Kushwaha, 1988b; Nanda and Bisoi, 1990; Shah *et. al.*, 2008). The use of systemic granular insecticides particularly phorate 10G and carbofuran 3G have increased tremendously for the last few years in this state. The practice of indiscriminate application of granules, besides destructing natural enemies, non target pest, contamination of environment and high level of residues in grains, has also resulted into the development of resistance, outbreak of rice leaf folder (Kushwaha, 1987). The information on resurgence of rice leaf folder is still lacking. Therefore, it was felt imperative to study the resurgence behavior of leaf folder following application of phorate granules.

MATERIALS AND METHODS

Field trials were conducted at the farm or Rice Research Station, Kaul (Kaithal). The 30 days old seedlings of variety HKR 120 were transplanted in the second week of July in 12 m^2 plots in randomized block design with three replications at a distance of 15 x 15cm. Phorate (Thimet 10G) granules were applied @ 0.5 and 1.0 Kg a.i./ha at 20, 40, 60, 20+40, 20+60, 40+60 and 20+40+60 days after transplanting (DAT). One treatment with 25% extra nitrogen over the recommended dose of 150 Kg N/ha along with a complete protection treatment from leaf folder attack by monocrotophos 36SL (Nuvacron) was maintained. For comparison one treatment of untreated (control) was also maintained. To avoid intermixing of treatments 50 cm thick mud boundaries were provided all around the plots. The

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provision was made to irrigate small plots separately with the help of irrigation channels. The calculated amount of granules were mixed with 90 g of dry sand (Khan and Kushwaha 1990) and broadcasted on water surface in the plot having 4-5 cm standing water. The plots meant for complete protection from planting till harvest were sprayed with Nuvacron 36SL @ 0.2 kg a.i./ha using Knap Sack sprayer on need basis with three sprays at 30, 50 and 70 DAT. Drifting from one plot to another was avoided by using polythene sheet at the time of spraying. An extra 25% N was applied in two split doses at 21 and 42 DAT in the plots meant for this treatment. These plots were also completely protected from leaf folder attack by the foliar application of Nuvacron 36SL. The observations on leaf folder incidence from 5 hills/plot and number of larvae/10 leaves/plot selected randomly were made at 70 and 80 DAT. The $1/3^{rd}$ or more affected leaf was considered as damaged one, whereas moribund larvae were considered as dead for counting larva population.

RESULTS AND DISCUSSION

Leaf damage : The data presented in Table 1 indicate that the leaf damage caused by the leaf folder larvae at 70 and 80 DAT ranged from 0.53 to 8.33 and 0.0 to 61.63 % in different treatments of phorate granules. At this observational period the plots treated with phorate @ 1.0 kg/ha at 20+40+60 DAT also showed higher leaf damage (8.33%) as compared to 6.94% in control plot (T_{17}). Phorate @ 0.5 kg/ha applied at 40+60 DAT and 20+40+60 DAT showed 56.4% and 59.5% damage as against 55.8% in untreated plot.

A comparable damage 57.4 (T_{13}) and 61.6% (T_{14}) was observed in the plots where higher dose (1.0 kg/ha) was applied. Leaf damage in lower dose conditions ranged from 4.5 to 6.7% at 70 DAT, whereas it ranged from 39.4 to 59.5% at 80 DAT. In case of higher dose, leaf damage in a range of 4 to 8% and 39.4 to 61.6% was noticed at 70 and 80 DAT, respectively. The plots having 25% extra nitrogen along with complete protection (T_{15}) and the plots protected completely with monocrotophos (T_{16}) exhibited a range of 0.66-0.67% and 0 to 0.53% leaf damage, respectively.

All the treatments except T_{14} had almost similar leaf damage, however, T_{14} had significantly higher leaf damage. The best leaf protection was achieved with the foliar application of monocrotophos 36SL @ 0.2 kg/ha,

Table 1. Effect of different treatments of phorate on the incidence of C. medinalis at different periods

Treatment	Dose kg a. i./ha	Time of application (DAT)	*Average leaves damaged		Mean (%)
			70 DAT	80 DAT	
Phorate 10G (T_1)	0.5	20	4.50 (12.23)	39.40 (38.88)	21.95
Phorate 10G (T_2)	0.5	40	5.05 (12.89)	49.36 (44.50)	27.20
Phorate 10G (T_3)	0.5	60	5.63 (13.73)	51.70 (45.98)	28.66
Phorate 10G (T_4)	0.5	20+40	4.93 (12.78)	42.70 (40.74)	23.81
Phorate 10G (T_5)	0.5	20+60	6.32 (14.55)	50.10 (44.90)	28.21
Phorate 10G (T_6)	0.5	40+60	6.36 (14.56)	56.36 (48.65)	31.36
Phorate 10G (T_7)	0.5	20+40+60	6.70 (15.00)	59.46 (50.07)	33.08
Phorate 10G (T_8)	1.0	20	5.97 (14.08)	39.40 (38.88)	22.68
Phorate 10G (T_9)	1.0	40	5.73 (13.85)	40.30 (39.40)	23.01
Phorate 10G (T_{10})	1.0	60	4.26 (11.79)	48.20 (43.58)	26.23
Phorate 10G (T_{11})	1.0	20+40	3.95 (11.42)	48.53 (44.34)	26.24
Phorate 10G (T_{12})	1.0	20+60	6.40 (14.58)	55.80 (48.31)	31.10
Phorate 10G (T_{13})	1.0	40+60	6.53 (14.80)	57.40 (49.25)	31.96
Phorate 10G (T_{14})	1.0	20+40+60	8.33 (16.70)	61.63 (51.72)	34.98
Urea+monocrotophos 36SL (T_{15})	25% N extra+0.2	21 & 42+30+50+70	0.66 (3.91)	0.67 (3.91)	0.66
Monocrotophos 36SL need based (T_{16})	0.2	30+50+70	0.53 (3.63)	0.00 (1.81)	0.26
Untreated (Control) (T_{17})	-	-	6.94 (15.25)	55.80 (48.33)	31.37
C. D. at 5%			(2.41)	(2.11)	

*Average of 3 replications each with 5 hills/plot.
DAT=Days after transplanting; Figures in parenthesis are angular transformed values.

showing 0.66 to 0.67% leaf damage at 70 and 80 DAT. Both these treatments (T_{15} and T_{16}) had very low leaf damage and were significantly superior to untreated control.

The leaf damage data clearly indicate that the resurgence of leaf folder was more during 70 to 80 DAT and the dose did not have very significant effect on resurgence. The data further revealed that there was no resurgence or heavy incidence of the pest when the soil systemic granular insecticides were not applied (T_{15} & T_{16}). However, the population of the leaf folder whatsoever was there was controlled by adopting need based recommended control measures (monocrotophos @ 0.2 kg/ha).

This clearly indicate that between 70-80 DAT is the most critical period for the flare up of this pest and during this period effective steps should be taken to effectively control the pest and harvest a good crop. The increase in the population can be attributed to the greenish colour of the crop which might have attracted more adults to lay eggs and ultimately increased leaf damage by the larvae of rice leaf folder. The present studies are in accordance with Jayaraj *et al.* (1976) who also recorded higher leaf folder incidence in the plots treated with phorate 10G @ 1.0, 1.5 and 2.5 kg/ha as compared to control plots. Chintalapati *et al*. (2015) reported higher population of rice leaf folder in plots where imidacloprid- and thiamethoxam were sprayed (17.5-217.5% over the untreated control).

Larval population : Observation on resurgence of rice leaf folder larvae at 70 DAT revealed that phorate applied @ 0.5 kg/ha had resurgence on the treatments made at 40+60 DAT (T_6) and 20+40+60 DAT (T_7) which respectively had 5.66 and 6.33 larvae/10 leaves as against 5.33 larvae/10 leaves in control (T_{17}) (Table 2). The higher dose of phorate i.e. 1.0 kg/ha, however, recorded the resurgence of leaf folder in the treatments made at 20+60DAT (T_{12}), 40+60DAT (T_{13}) and 20+40+60 DAT (T_{14}) and respectively had 6.00, 5.66 and 7.00 larvae/10 leaves as compared to 5.33 larvae per 10 leaves in control T_{17} (Table 2). However, when the observations were made at 80 DAT there were 6.66 larvae/10 leaves in the plots treated three times (T_7) with phorate @ 0.5 kg/ha, 6.33 and 7.66 larvae/10 leaves in the plots treated at 40+60 DAT (T_{13}) and 20+40+60 DAT (T_4), respectively. The number of larvae in the treated plots was higher than the larvae found in control plots, T_{17} (5.66 larvae/ 10 leaves) which clearly indicate the resurgence of the pest. The present results are in conformity of the findings

Table 2. Effect of different phorate treatments on the larvae of C. medinalis at different periods.

Treatment	Dose kg a. i./ha	Time of application (DAT)	*Average no. larvae/10 leaves		% increase (+) or decrease (-) over control
			70 DAT	80 DAT	
Phorate 10G (T_1)	0.5	20	4.00 (2.22)	4.00 (2.22)	-29.3
Phorate 10G (T_2)	0.5	40	6.00 (2.63)	3.00 (1.98)	-46.9
Phorate 10G (T_3)	0.5	60	3.66 (2.15)	4.33 (2.29)	-23.5
Phorate 10G (T_4)	0.5	20+40	4.00 (2.22)	4.00 (2.22)	-29.3
Phorate 10G (T_5)	0.5	20+60	5.00 (2.42)	4.66 (2.30)	-17.6
Phorate 10G (T_6)	0.5	40+60	5.66 (2.56)	5.33 (2.49)	-5.8
Phorate 10G (T_7)	0.5	20+40+60	6.33 (2.29)	6.66 (2.76)	+17.6
Phorate 10G (T_8)	1.0	20	4.66 (2.37)	3.00 (1.98)	-46.9
Phorate 10G (T_9)	1.0	40	4.00 (2.33)	3.66 (2.14)	-10.7
Phorate 10G (T_{10})	1.0	60	4.33 (2.30)	4.00 (2.22)	-29.3
Phorate 10G (T_{11})	1.0	20+40	4.66 (2.36)	4.00 (2.22)	-29.3
Phorate 10G (T_{12})	1.0	20+60	6.00 (2.63)	5.00 (2.43)	-11.6
Phorate 10G (T_{13})	1.0	40+60	5.66 (2.57)	6.33 (2.69)	+11.8
Phorate 10G (T_{14})	1.0	20+40+60	7.00 (2.82)	7.66 (2.93)	+35.3
Urea+Monocrotophos 36SL (T_{15})	25% N extra + 0.2	21 & 42 +30+50+70	0.66 (1.27)	1.00 (1.38)	-82.3
Monocrotophos 36SL need based (T_{16})	0.2	30+50+70	0.00 (1.00)	0.33 (1.13)	-94.1
Untreated (Control) (T_{17})	-	-	5.33 (2.50)	5.66 (2.43)	-
C. D. at 5%			(0.45)	(0.39)	-

*Average of 3 replications each with 50 leaves/plot.
Figures in parenthesis are $\sqrt{n+1}$ values.

of Panda and Shi (1989) and Kushwaha (1987) who reported relatively higher larval population in carbofuran 3G and phorate 10G treated plots than the larvae in control plots.

Considering the extent of control, the maximum 82.33 to 100 % reduction in larval population was obtained by giving 3 rounds of foliar application of Monocrotophos 36SL, when needed (1 larva/hill). @ 0.2 kg/ha at 30, 50 and 70 DAT (T_{16}).

Effect of different treatments on the yield traits : The yield data (Table 3) collected from phorate treated plots clearly indicated that the grain yield obtained from various treatments were invariably higher (59.11 to 71.50 q/ha) than control (59.00 q/ha) except in the treatments of phorate @ 1.0 kg/ha applied at 20+40+60 DAT (T_{14}), T_7 (56.50q/ha). The plots treated with 25% extra nitrogen (T_{15}) gave an additional 12.50q/ha grain yield. Amongst the phorate treated plots the highest 1.55q/ha increase in grain yield was observed in the plots treated with phorate @ 0.5 kg/ha at 20+60 DAT (T_5) showing thereby a net profit of Rs. 14.00/ha only.

The net profit due to application of different doses of phorate did not exceed Rs. 193.20/ha in either of the doses of phorate treatments. There was a net loss of Rs. 686.00, Rs. 1031.60 and Rs. 1840.00/ha due to decrease in yield following the phorate application @ 0.5 and 1.0 kg/ha at 40+60 DAT (T_{13}) and 20+40+60 DAT (T_{14}), respectively because of increased leaf folder resurgence. No cost benefit ratio was achieved in any of the treatments following the application of granular insecticides. Cost benefit ratio of 1:2.45 and 1:2.69; however was achieved from the plots kept completely free from leaf folder attack (T_{16}) while the plots having 25% extra nitrogen with complete protection also showed a cost benefit ratio of 1:2.40.

Table 3. Economics of different treatments applied for the control of C. medinalis

Treatment	Dose kg a.i./ha	Time of application (DAT)	Yield (q/ha)	Increased (+) or decrease (-) in yield over control (q/ha)	Value of increased or decreased grain yield (Rs./ha)	Cost of treatment (Rs./ha)	Net profit (Rs.)	Cost benefit ratio
Phorate 10G (T_1)	0.5	20	60.44	1.44	403.2	210	193.2	-
Phorate 10G (T_2)	0.5	40	60.00	1.00	280.0	210	70.0	-
Phorate 10G (T_3)	0.5	60	59.80	0.80	224.0	210	14.0	-
Phorate 10G (T_4)	0.5	20+40	59.55	0.55	154.0	420	-266.0	-
Phorate 10G (T_5)	0.5	20+60	60.55	1.55	434.0	420	14.0	-
Phorate 10G (T_6)	0.5	40+60	59.11	0.11	30.8	420	-389.2	-
Phorate 10G (T_7)	0.5	20+40+60	58.80	-0.20	-56.8	630	-686.0+	-
Phorate 10G (T_8)	1.0	20	60.45	1.45	406.0	380	26.0	-
Phorate 10G (T_9)	1.0	40	60.14	1.14	319.2	380	-60.8	-
Phorate 10G (T_{10})	1.0	60	60.11	1.11	310.8	380	-69.2	-
Phorate 10G (T_{11})	1.0	20+40	59.63	0.63	176.4	760	-583.6	-
Phorate 10G (T_{12})	1.0	20+60	59.64	0.64	179.2	760	-580.8	-
Phorate 10G (T_{13})	1.0	40+60	58.03	-0.97	-271.6	760	-1031.6+	-
Phorate 10G (T_{14})	1.0	20+40+60	56.50	-2.50	-700.0	1140	-1840.0+	-
Urea+Monocrotophos 36SL (T_{15})	25% N extra+0.2	21 & 42 +30+50+70	71.50	12.50	3500.0	1029	2471.0	1:2.40
Monocrotophos 36SL need based (T_{16})	0.2	30+50+70	69.30	10.30	2884.0	780	2104.0	1:2.69
Untreated (Control) (T_{17})	-	-	59.00	-	-	-	-	-
C. D. at 5%			1.28					

+Loss due to leaf folder resurgence+cost of treatment.

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Screening of okra genotypes against leafhopper, *Amrasca biguttula biguttula* (Ishida) (Homoptera: Cicadellidae)

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ABSTRACT

Okra is one of the important crop of India having a good potential to earn foreign exchange for its large scale export. Leafhopper, *Amrasca biguttula biguttula* (Ishida) is the major constraint threatening the yield of this crop. Keeping in view the importance of crop twenty three genotypes of okra were screened under field conditions against *A. biguttula biguttula* during rainy seasons of 2010 and 2011. Based on two years data four less susceptible genotypes (Hisar Naveen, HBT 36, HBT 41, HBT 12), 3 intermediate susceptible (Varsha Uphar, HBTC 6-7-1, HBT 49-1) and 2 highly susceptible genotypes (HBT 15, HBT 35-1) were selected for further screening during 2012. Differences were found to be significant among genotypes of okra during 2010, 2011 and 2012. Overall, genotype HBT 35-1 showed maximum population of leafhopper nymphs followed by HBT 49-1, two genotypes (HBT 12 and HBT 36) showed minimum population of leafhopper nymphs (3.32) followed by Hisar Naveen HBT 41 (3.81), Varsha Uphar (4.32), HBTC 6-7-1 (4.46), HBT 15 (4.87).

Key words : Okra, leafhopper, *Amrasca biguttula biguttula*, screening, genotypes

INTRODUCTION

Okra, or Ladies finger, which is also known as '*Bhindi*', is one of the important vegetables of India. It is grown throughout the tropical and sub-tropical regions and also in the warmer parts of the temperate regions. The nutritional value of 100 g of edible okra is characterized 1.9 g protein, 0.2 g fat, 6.4 g carbohydrate, 0.7 g minerals and 1.2 g fibers. Okra has a good potential to earn foreign exchange and accounts for 60% of the export of fresh vegetables. It is cultivated in 0.349 m ha area with the production of 3.344 m t and productivity of 9.6 mt/ha (Anonymous, 2014). The major okra producing states are Uttar Pradesh, Bihar, Orissa, West Bengal, Andhra Pradesh and Karnataka. In West Bengal, 0.662 mt of Okra is produced from 58,400 ha with an average productivity of 11.4 mt/ha. The crop is also used in paper and sugar industry as well as for the extraction of fiber. (http://www.ncpahindia.com/okra.php) dated 4-1-2015.

It is attacked by a variety of pests *viz*. leafhopper (*Amrasca biguttula biguttula*), spotted shoot and fruit borer (*Earias* spp.), aphid (*Aphis gossypii*), whitefly (*Bemisia tabaci*), thrips (*Thrips tabaci*) and red cotton bug (*Dysdercus cingulatus*) that hinder its yield (Devasthali and Seran, 1997). *A. biguttula biguttula*, *A. gossypii* and *Earias* spp. has been reported to cause heavy yield reduction (Pathan *et al*. 2010). Leafhopper, *A. biguttula biguttula* is amongst the most important sucking insects that attack okra crop where it lays maximum number of eggs and thus becomes suitable place for survival and feeding (Bernardo and Taylo, 1990; Sharma and Singh, 2002). About 59.79% loss in okra fruit yield has been reported by leafhopper alone (Atwal and Singh, 1990). Though the pest can be effectively controlled with the use of insecticides but yearly increase in the cost has gone out of the reach of common farmer. Besides insecticide use poses several problems like health hyzards, environmental pollution, pest resurgence *etc*. The present study was an attempt to identify the response of leafhopper to different available genotypes of okra in order to determine resistance/susceptibility.

MATERIALS AND METHODS

Studies were carried out during 2010 and 2011 to screen okra genotypes based on leafhopper nymphs population per leaf. Twenty three genotypes of okra were sown in Randomized Block Design (RBD) in the experimental area of Vegetable Farm, CCS Haryana Agricultural University, Hisar (Table-1). Based on observations of two years, nine genotypes showing resistance (Hisar Naveen, HBT 36, HBT 41, HBT 12), intermediate susceptibility (Varsha Uphar, HBTC 6-7-1, HBT 49-1) and high susceptibility (HBT 15, HBT 35-1) for leafhopper were selected for experiments during 2012. Experiments were laid out in a RBD with four replications during rainy season, 2012. The row to row and plant to plant distance was maintained 60 and 30 cm, respectively. All the recommended agronomic practices except plant protection measures were adopted to raise the good crop.

Leafhopper nymph population was recorded from 12 tagged plants of each genotype in each replication selected at random from upper, middle and lower fully expanded leaves. Nymphs population was recorded during morning hours at two week interval. Square root transformation of the collected data for leafhopper was being done and its statistical analysis of variance was carried out.

RESULTS AND DISCUSSION

The data presented in Table 1 revealed significant difference among genotypes during both the years. In 2010, nine genotypes (HBT 12, HBT 36, HBT 13, HBT 1, HBTC 6-7-1, HBT 6, Hisar Naveen, HBT 41 and HBT 32) were found at par with each other and showed leafhopper nymphs population from 3.08 to 4.85/leaf. Ten genotypes (HBT 69-1, Varsha Uphar, HBT 51-1, HBT 69, HBT 55, HBT 3, HBT 56, HBT 32-1, HBT 35 and HBT 33-2-1) showed leafhopper nymphs population from 5.57 to 8.13/leaf and were found at par with each other. Maximum leafhopper

Table 1. Means population of leafhopper nymphs per leaf on different genotypes of okra during 2010 & 2011

Genotypes	Mean (2010)	Mean (2011)	Pooled mean
Varsha Uphar	5.90 (2.622)b	3.08 (2.010)a	4.21 (2.280)b
Hisar Naveen	4.00 (2.229)a	2.07 (1.734)a	2.84 (1.955)a
HBT 36	3.20 (2.023)a	3.18 (2.034)a	3.19 (2.039)a
HBT 1	3.65 (2.128)a	4.48 (2.331)b	4.15 (2.263)b
HBT 3	6.77 (2.774)b	5.27 (2.498)c	5.87 (2.616)c
HBT 13	3.35 (2.061)a	3.55 (2.128)b	3.47 (2.111)a
HBT 32	4.85 (2.358)a	4.70 (2.378)b	4.76 (2.385)b
HBT 32-1	7.93 (2.942)b	3.87 (2.187)b	5.49 (2.542)c
HBT 33-2-1	8.13 (2.965)b	5.99 (2.636)c	6.85 (2.781)c
HBT 35	8.00 (2.973)b	6.67 (2.752)c	7.20 (2.852)d
HBT 35-1	8.72 (3.107)c	3.58 (2.131)b	5.63 (2.573)c
HBT 41	4.67 (2.374)a	2.12 (1.760)a	3.14 (2.032)a
HBT 45	8.68 (3.098)c	4.59 (2.363)b	6.23 (2.684)c
HBT 51-1	6.12 (2.660)b	3.86 (2.202)b	4.76 (2.397)b
HBT 55	6.30 (2.694)b	3.84 (2.197)b	4.82 (2.409)b
HBT 56	7.55 (2.971)b	3.99 (2.229)b	5.41 (2.525)c
HBT 69	6.13 (2.663)b	3.10 (1.990)a	4.31 (2.299)b
HBT 69-1	5.57 (2.550)b	5.61 (2.546)c	5.59 (2.554)c
HBTC-6-7-1	3.77 (2.179)a	4.36 (2.312)b	4.12 (2.262)b
HBT 12	3.08 (2.007)a	3.46 (2.078)b	3.31 (2.067)a
HBT 49-1	9.70 (3.254)c	2.21 (1.782)a	5.21 (2.488)b
HBT 6	3.87 (2.199)a	2.65 (1.893)a	3.13 (2.027)a
HBT 15	8.27 (3.032)c	3.62 (2.148)b	5.48 (2.544)c
C.D.	0.452	(0.312)	(0.241)
SE(m)	0.16	(0.111)	(0.086)
SE(d)	2.27	(0.157)	(0.121)
C.V.	13.803	(11.323)	(8.050)

Table 2. Leafhopper nymphs population per leaf during different years on promising genotypes

Genotypes	Mean (2010)	Mean (2011)	Mean (2012)	Av. 2010-2012
Varsha Uphar	5.90 (2.622)	3.08 (2.010)	3.98 (2.224)c	4.32 (2.29)
Hisar Naveen	4.00 (2.229)	2.07 (1.734)	4.35 (2.306)c	3.47 (2.09)
HBT 36	3.20 (2.023)	3.18 (2.034)	3.59 (2.136)b	3.32 (2.06)
HBT 35-1	8.72 (3.107)	3.58 (2.131)	4.57 (2.359)c	5.62 (2.53)
HBT 41	4.67 (2.374)	2.12 (1.760)	4.63 (2.365)d	3.81 (2.17)
HBTC 6-7-1	3.77 (2.179)	4.36 (2.312)	5.25 (2.491)d	4.46 (2.33)
HBT 12	3.08 (2.007)	3.46 (2.078)	3.41 (2.094)b	3.32 (2.06)
HBT 49-1	9.70 (3.254)	2.21 (1.782)	3.30 (2.065)b	5.07 (2.37)
HBT 15	8.27 (3.032)	3.62 (2.148)	2.72 (1.925)a	4.87 (2.37)
C.D.	-	-	(0.138)	-
C.V.	-	-	(7.647)	-

nymphs population was recorded in genotypes HBT 49-1 (9.70/leaf) followed by HBT 35-1, HBT 45 and HBT 15.

During the year 2011, leafhopper nymphs population were minimum (2.07 to 3.18/leaf) and at par with each other on 7 genotypes (Hisar Naveen, HBT 41, HBT 49-1, HBT 6, Varsha Uphar, HBT 69 and HBT 36). Whereas 12 genotypes (HBT 12, HBT 13, HBT 35-1, HBT 15, HBT 55, HBT 51-1, HBT 32-1, HBT 56, HBT 6-7-1, HBT 1, HBT 45 and HBT 32) showed leafhopper nymphs population from 3.55 to 4.70/leaf and were found at par with each other. Maximum leafhopper nymphs population were recorded on genotypes HBT 35 (6.67) followed by HBT 33-2-1 (5.99), HBT 69-1 (5.61) and HBT 3 (5.27).

Pooled data of both years revealed that six genotypes (Hisar Naveen, HBT 6, HBT 41, HBT 36, HBT 12 and HBT 13) were found at par with each other with leafhopper nymphs population from 2.84 to 3.47/leaf and can be considered as resistant/less susceptible. While eight genotypes (HBTC 6-7-1, HBT 1, Varsha Uphar, HBT 69, HBT 51-1, HBT 32, HBT 55 and HBT 49-1) showed population in between 4.12 to 5.21 and can be considered under moderately susceptible against leafhopper. However, maximum population of leafhopper nymphs were observed on genotypes HBT 35 (7.20) followed by HBT 33-2-1 (6.85), HBT 45 (6.23) HBT 3 (5.87), HBT 35-1 (5.63), HBT 69-1 (5.59), HBT 32-1 (5.49), HBT 15 (5.48) and HBT 56 (5.41).

Based on pooled data of 2 years, nine genotypes (**resistant/less susceptible**: Hisar Naveen, HBT 36, HBT 12 and HBT 41; **moderately susceptible:**Varsha Uphar, HBTC 6-7-1 and HBT 49-1; **susceptible/highly susceptible :** HBT 15 and HBT 35-1) were selected for further screening against leafhopper during 2012. The data presented in Table 2 revealed that all the genotypes differed significantly. Minimum leafhopper nymph population was recorded on genotype, HBT 15 (2.72/leaf) followed by HBT 36, HBT 12, HBT 49-1 and these were at par with each other. Three genotypes (Varsha Uphar, Hisar Naveen and HBT 35-1) were found at par with each other with leafhopper nymphs population from 3.98 to 4.57/leaf. However, two genotypes (HBT 41 and HBTC 6-7-1) showed maximum leafhopper nymphs population and were at par with each other. The results are in accordance of findings of Verma *et al.* (2013) who reported leafhopper nymphs population less than 4.0 on genotypes HBT 15, HBT 36, HBT 12, HBT 49-1, Varsha Uphar, Hisar Naveen, HBT 35-1 and HBT 41.

On the mean basis of three year data, HBT 36 and HBT 12 showed minimum population of leafhopper nymphs i.e. 3.32/leaf followed by Hisar Naveen (3.47), HBT 41 (3.81), Varsha Uphar (4.32), HBTC 6-7-1 (4.46), HBT 15 (4.87), HBT 49-1 (5.07), HBT 35-1 (5.62) (Table 2).

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Effect of different tree species on physico-chemical properties of soil in a semi arid environment

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ABSTRACT

Block plantation, in 1 ha of five multipurpose tree species of arid and semi arid region *viz. Prsopis cineraria, Dalbergia sissoo, Acacia nilotica, Eucalyptus tereticornis* and *Tamarix aphylla* of about 15-20 years old were selected for determining the physico- chemical properties of soil. Soil samples at the depth of 0-4, 4-15, 15-30, 30-60, 60-90, 90-120 and 120-150 cm were collected from the soils under each tree species and also from the soil which were devoid of trees. The physico-chemical properties of these soil samples were determined by adopting standard procedures. The organic carbon, pH, EC, bulk density, particle density and $CaCO_3$ content decreased significantly in control as well as under all tree plantations with the increase in depth. In comparison to control, the pH, EC, bulk density and $CaCO_3$ content were lower in soils under all the tree species. The higher amount of organic carbon content in soils under tree plantations as compared to control may be the probable reason for this type of physico-chemical properties.

Key words : Tree species, physico-chemical properties, soil depth, organic carbon, semi arid

INTRODUCTION

The incorporation of leaf biomass of different tree species has been found very successful and hence widely adapted for improving the physico-chemical characteristics and nutrient status of the soil (Singh and Sharma, 2012). It is likely that differences in plant species traits will create distinctive soil environment and species-specific impact on soil physical, chemical and biological properties were observed (Eviner, 2004 and Ayres *et al.*, 2009). Trees exercise short and long term effects on physico-chemical and biological properties of soils. In short term when litter decomposes as a result of microbial activity, the nutrients contained within it may follow two paths- mineralization and/or humification. Long term effects are governed by changes in soil nutrients reserve over the years from regular additions of pruning and root turn over. In view of the importance of litter fall on the soil physico-chemical properties and nutrient release pattern, there is a much need to characterize the surface soil litters for its proper management. The understanding of nutrient availability may also pave the way for getting sustainable production from intercropping. The studies on the influence of tree species on the soil physico-chemical properties are lacking in Haryana. Therefore, the depth-wise physico-chemical properties in soil profile were determined under multipurpose tree species of the region.

MATERIALS AND METHODS

Study site and climate

The present investigation was carried out at Research Farm of Department of Agroforestry, CCS Haryana Agricultural University Hisar which is located at 29°10'N latitude and 75°46'E longitude at an altitude of 215 m above mean sea level. It has a semi arid and sub tropical climate with hot, dry and desiccating winds during summer and severe cold during winter season. The mean monthly maximum temperature during summer months (May to July) reaches up to 42 to 45°C, while the minimum temperature during winter months (December and January) sometimes goes as low as 0°C or even less. Average rainfall varies from 353 to 447 mm, most of which is received during the months of July-August and few showers of cyclonic rains are received in winter or late springs. The average wind speed is about 7 kmph.

Collection of soil sample

Block plantation (minimum one hectare) of five multipurpose tree species of arid and semi-arid region *viz.*, *Prosopis cineraria*, *Dalbergia sissoo*, *Acacia nilotica*, *Eucalyptus tereticornis* and *Tamarix aphylla* of about 15 to 20 years old were selected. From each block, one tree, which was surrounded by the trees of the same species on all sides, was selected. From the base of tree, four points at a distance of one meter in east, west, north and south directions were marked. From these points, with the help of an auger, soil samples were collected. Initially, the thickness of litter on the surface was measured and the decomposed and undecomposed litter was collected separately. In all, seven samples (one leaf litter up to depth of 0-4 cm and six soil samples *viz.*, 4-15, 15-30, 30-60, 60-90, 90-120 and 120 to 150 cm were collected from one point. To make two replicates, depth wise samples collected in north and west directions and east and south directions were mixed together to make two replications. In this way, seven depth wise samples with two replications were collected from the block plantation of each tree species. Similarly, soil samples were collected from nearby area of plantation which was devoid of trees and was undisturbed. In this way, soil samples were collected from block plantation and area adjacent to the plantation but devoid of any plantation except natural vegetation.

Chemical analysis of soil samples

Soil samples were air dried, ground by a pestle and mortar and passed through 2 mm sieve. These samples were stored in poly bags for further analysis. The samples were analyzed for pH, EC, Bulk density, Particle density and $CaCO_3$ content. The pH and EC were determined in 1:2 soil water suspension, Bulk density by core method (Singh, 1980), Particle density by standard psychometer method using disturbed soil sample (Richards, 1954) and $CaCO_3$ content by Puri's volumetric method (1941) method as outlined by Chopra and Kanwer (1991).

Statistical analysis

The data of different soil properties were subjected to statistical analysis using ANOVA technique in split plot design by taking tree species (including control) in main plots and soil depths in sub-plots. Mean separation was done with the critical difference (CD) test at 5% level of significance (Panse and Sukhatme, 1985).

RESULTS AND DISCUSSION

Effect of different tree species on various physico-chemical characteristics of soil have been discussed under the following headings.

Organic carbon

Organic carbon content was higher in 0-4 cm layer in control as well as under different plantations (Table 1). There was a significant decrease in organic carbon content with increase in soil depth which was due to high biomass accumulation on the surface layer.

Table 1. Organic carbon content (%) of soils under different plantations

Depth (cm)	Tree species						
	Control	*Dalbergia sissoo*	*Prosopis cineraria*	*Eucalyptus tereticornis*	*Acacia nilotica*	*Tamarix aphylla*	Mean
0-4	0.46	1.60	1.20	1.00	1.50	1.20	1.16
4-15	0.38	0.64	0.78	0.36	0.90	0.39	0.66
15-30	0.38	0.62	0.55	0.33	0.74	0.36	0.64
30-60	0.34	0.42	0.39	0.25	0.52	0.33	0.50
60-90	0.27	0.41	0.36	0.16	0.43	0.30	0.46
90-120	0.22	0.33	0.33	0.15	0.38	0.21	0.40
120-150	0.21	0.33	0.32	0.15	0.36	0.18	0.26
Mean	0.32	0.62	0.59	0.34	0.69	0.42	

C D (p=0.05) Depth : 0.05 Tree species : 0.05 Depth x Tree species : 0.14

Table 2. pH (1:2 soil water suspension) of soils under different plantations

Depth (cm)	Tree species						
	Control	*Dalbergia sissoo*	*Prosopis cineraria*	*Eucalyptus tereticornis*	*Acacia nilotica*	*Tamarix aphylla*	Mean
0-4	7.7	7.4	7.5	7.6	7.4	7.6	7.53
4-15	7.8	7.5	7.6	7.7	7.8	7.7	7.68
15-30	7.9	7.6	7.8	7.7	7.8	7.7	7.75
30-60	7.9	7.6	7.9	7.9	7.8	7.7	7.80
60-90	7.9	7.6	8.0	7.9	8.0	7.9	7.83
90-120	8.1	7.8	8.0	8.0	8.0	7.9	7.97
120-150	8.2	7.8	8.1	8.1	8.1	8.0	8.05
Mean	7.9	7.6	7.8	7.8	7.8	7.8	

C D (p=0.05) Depth : NS Tree species : NS Depth x Tree species : NS

Patel *et al.* (2010) and Thakur *et al.* (2012) also observed higher organic carbon in surface layers and gradual decrease downwards in soils under tree plantation. The highest amount of organic carbon (1.6%) was observed under surface layer of *Dalbergia sissoo* plantation which was followed by *Acacia nilotica* (1.5%), *Prosopis cineraria* and *Tamarix aphylla* (1.2% each) and *Eucalyptus tereticornis* (1.0%). Among different tree species, highest amount of organic carbon accumulation in soil profile was observed under *Acacia nilotica* followed by *Dalbergia sissoo*, *Prosopis cineraria*, *Tamarix aphylla* and *Eucalyptus tereticornis*. The variation in organic carbon accumulation in soils under different plantation may be attributed possibly to the difference in type of vegetation, litter composition and its humification. Comparatively, higher accumulation of organic carbon in soils under *Dalbergia sissoo* and *Acacia nilotica* may be attributed to the higher annual biomass production by these tree species (Kumar *et al.*, 1998 and Prasad *et al.*, 1991).

Soil pH

Soil pH increased with increasing depth from 7.7 (surface) to 8.2 (lower most depth) in control (Table 2). Under different plantations, these values varied from 7.4 to 7.8, 7.5 to 8.1, 7.6 to 8.1, 7.4 to 8.1 and 7.6 to 8.0 in *Dalbergia sissoo*, *Prosopis cineraria*, *Eucalyptus tereticornis*, *Acacia nilotica* and *Tamarix aphylla*, respectively. At upper layers (0-4 and 4-15 cm), the pH in soil under different plantations decreased as compared to control and maximum reduction in soil pH was observed under *Dalbergia sissoo*. Reduction in soil pH under different plantations especially at top layer might be attributed to higher organic matter accumulation and its subsequent decomposition, resulting in to formation

Table 3. EC [1:2 soil water suspension (dSm^{-1})] of soils under different plantations

Depth (cm)	Tree species						
	Control	*Dalbergia sissoo*	*Prosopis cineraria*	*Eucalyptus tereticornis*	*Acacia nilotica*	*Tamarix aphylla*	Mean
0-4	0.93	0.18	0.19	0.58	0.36	0.22	0.30
4-15	0.98	0.20	0.20	0.94	0.38	0.23	0.39
15-30	1.13	0.23	0.23	1.07	0.41	0.41	0.47
30-60	1.33	0.26	0.35	1.32	0.46	0.44	0.56
60-90	1.76	0.26	0.35	1.42	0.62	0.44	0.61
90-120	1.78	0.33	0.36	1.78	0.68	0.49	0.72
120-150	2.10	0.41	0.38	1.81	0.92	0.51	
Mean	1.43	0.27	0.29	1.27	0.55	0.39	

C D (p=0.05) Depth : 0.01 Tree species : 0.01 Depth x Tree species : 0.03

of organic acids and acid producing substances (Nandi *et al.*, 1991 and van Haren *et al.*, 2013).

Electrical conductivity

Electrical conductivity of soils increased with increased depth in case of control as well as all the tree species (Table 3). In general, the EC was higher in control as compared to the tree species. In case of control, the EC varied from 0.93 dSm^{-1} at surface layer to 2.10 dSm^{-1} at 120-150 cm layer. Among the tree species, the highest value of EC was observed in case of *Eucalyptus tereticornis* (0.58 to1.81 dSm^{-1}) and lowest in case of *Dalbergia sissoo* (0.18 to 0.41 dSm^{-1}). It is evident from the data that all the tree species helped in lowering down the salt concentration in soil. The reduction was maximum under *Dalbergia sissoo*. The effectiveness of different tree species in improving soil by lowering its EC values might be attributed to its relative tolerance under adverse soil conditions, amount of litter fall and its chemical composition. The results are in conformity with the findings of Kumar *et al.* (1998) and Nandi *et al.* (1991).

Bulk density

Bulk density of the soils in the profile ranged from 1.45 to 1.58, 1.36 to 1.57, 1.38 to 1.56, 1.36 to 1.53, 1.30 to 1.56 and 1.32 to 1.52 Mgm^{-3} in case of control, under plantations of *Dalbergia sissoo*, *Prosopis cineraria*, *Tamarix aphylla*, *Eucalyptus tereticornis* and *Acacia nilotica*, respectively (Table 4). In general, the bulk density increased with the increasing depth both in the soil under tree plantations and control. On an average, the bulk density was found higher in control in comparison to tree species which might be due to their

Table 4. Bulk density (Mgm^{-3}) of soils under different plantations

Depth (cm)	Tree species						
	Control	*Dalbergia sissoo*	*Prosopis cineraria*	*Eucalyptus tereticornis*	*Acacia nilotica*	*Tamarix aphylla*	Mean
0-4	1.45	1.36	1.38	1.30	1.32	1.36	1.36
4-15	1.46	1.38	1.40	1.33	1.36	1.39	1.38
15-30	1.48	1.42	1.46	1.36	1.39	1.46	1.43
30-60	1.51	1.49	1.49	1.37	1.42	1.47	1.46
60-90	1.53	1.49	1.49	1.45	1.46	1.49	1.48
90-120	1.58	1.52	1.51	1.52	1.48	1.49	1.51
120-150	1.58	1.57	1.56	1.56	1.52	1.53	1.55
Mean	1.51	1.46	1.47	1.41	1.42	1.36	

C D (p=0.05) Depth : 0.12 Tree species : NS Depth x Tree species : NS

Table 5. Particle density (Mgm^{-3}) of soils under different plantations

Depth (cm)	Tree species						
	Control	*Dalbergia sissoo*	*Prosopis cineraria*	*Eucalyptus tereticornis*	*Acacia nilotica*	*Tamarix aphylla*	Mean
0-4	2.43	2.00	2.04	2.08	2.12	2.32	2.16
4-15	2.49	2.02	2.53	0.46	2.55	2.55	2.43
15-30	2.53	2.08	2.64	0.44	2.58	2.57	2.47
30-60	2.64	2.13	2.69	0.55	2.73	2.63	2.56
60-90	2.67	2.13	2.69	0.56	2.76	2.65	2.58
90-120	2.75	2.75	2.73	0.76	2.85	2.66	2.75
120-150	2.84	2.84	2.82	0.85	2.86	2.71	2.82
Mean	2.62	2.28	2.59	2.53	2.64	2.58	

C D (p=0.05) Depth : 0.01 Tree species : 0.01 Depth x Tree species : 0.03

Table 6. $CaCO_3$ (%) of soils under different plantations

Depth (cm)	Tree species						
	Control	*Dalbergia sissoo*	*Prosopis cineraria*	*Eucalyptus tereticornis*	*Acacia nilotica*	*Tamarix aphylla*	Mean
0-4	0.5	0.0	0.0	0.0	0.0	0.0	0.08
4-15	0.8	0.6	0.6	0.7	0.7	0.9	0.71
15-30	1.2	0.7	1.4	1.3	1.2	1.4	1.20
30-60	2.2	1.1	1.8	2.2	1.4	1.2	1.6
60-90	2.0	2.3	2.4	2.8	2.2	1.6	2.2
90-120	2.7	2.7	2.2	2.3	2.9	2.4	2.5
120-150	3.9	3.7	3.2	2.9	3.1	2.8	3.2
Mean	1.9	1.6	1.6	1.7	1.6	1.5	

C D (p=0.05) Depth : NS Tree species : NS Depth x Tree species : NS

higher organic carbon content (Celik, 2005 and van Haren *et al.*, 2013). The differences between the values of bulk density of surface and sub surface depths in general, were more in case of soils under tree plantation than control. This seems to be due to the differences in organic carbon content of surface and sub-surface layers.

Particle density

The data presented in Table 5 revealed that particle density in soil profile varied from 2.43 to 2.84, 2.00 to 2.84, 2.04 to 2.82, 2.08 to 2.85, 2.12 to 2.86, 2.32 to 2.71 Mgm^{-3} in control, under plantations of *Dalbergia sissoo*, *Prosopis cineraria*, *Eucalyptus tereticornis*, *Acacia nilotica* and *Tamarix aphylla*, respectively (Table 5). The particle density of soils increased significantly with increasing depth in control as well as under all the tree species. The maximum reduction in particle density in upper most layer under *Dalbergia sisso* might be due to higher annual litter return as compared to other tree species (Hosur and Dasog, 1995). The increase in particle density with increasing depth may be due to increase in clay and silt fraction and reduction in organic matter content with depth. Similar observations were observed by Kumar *et al.* (1998).

Calcium carbonate

A perusal of data in Table 6 revealed that the $CaCO_3$ content varied from 0.5 to 3.9, 0 to 3.7, 0 to 3.2, 0 to 3.1, 0 to 2.9 and 0 to 2.8 per cent in control, *Dalbergia sissoo*, *Prosopis cineraria*, *Acacia nilotica*, *Eucalyptus tereticornis* and *Tamarix aphylla*, respectively. On an average basis maximum $CaCO_3$ content was recorded 1.9 per cent and 1.7 per cent in control and *Eucalyptus tereticornis*, respectively and minimum (1.5 %) in *Tamarix aphylla*. Accumulation of $CaCO_3$ on the surface layer was less as compared to deeper layer in the soils.

The physico-chemical properties of soil under different plantations were found different as compared to the soil under no plantation. The organic carbon, pH, EC, bulk density, particle density and $CaCO_3$ content were decreased significantly with the increase in depth. In comparison to control, the pH, EC, bulk density and $CaCO_3$ content were lower in soils under all the tree species. However, the organic carbon content in soils under tree plantations was higher as compared to control.

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